Disaster risk management in rural New Zealand

A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Disaster Risk and Resilience

by

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Abstract

Natural hazards can have substantial and enduring disaster impacts on rural communities. They impact human lives, infrastructure, and economies, but can also powerfully influence rural culture, sense of community, and business continuity. Rural regions are home to nearly half of the world's population, and these areas make vital contributions to many national economies, through primary economic activities, transportation, and tourism. The consequences of disaster impacts in rural regions can be felt across scales and have lasting local, national, and international repercussions. Furthermore, demographic trends and climate change are rapidly changing the underlying drivers of disaster risk in rural areas.

Effective disaster risk management (DRM) is essential to enable rural regions to reduce, prepare for, and manage the risks to society and organisations from hazard events. There is an extensive literature on disasters and rural DRM in low-income nations. However, DRM studies in high-income nations tend to focus on densely populated urban centres. Applying proven DRM policies and practices in urban centres may not necessarily be suited for the specific needs of rural regions following a disaster. While the Sendai Framework for Disaster Risk Reduction 2015 – 2030 encourages participation and collaboration in DRM planning and implementation, there is as yet, no commonly accepted method for achieving this. Advancing our understanding of rural-specific disaster vulnerabilities and capacities in high-income nations, and analysis of decision-making methods that emphasise rural DRM collaboration, will therefore improve DRM strategies and enhance rural disaster resilience.

To address these gaps, this thesis presents qualitative empirical results, supplemented with geospatial assessment, on rural disaster risk management in New Zealand. There are three objectives: (1) identify the key drivers of disaster risk in rural New Zealand, (2) map the institutional and social structures that inform, enable and constrain DRM decision-making in rural New Zealand in response to those drivers, and (3) identify opportunities to enhance effectiveness of rural DRM within the New Zealand context.

Rural New Zealand presents unique advantages and challenges in the field of disaster resilience; New Zealand is a high-income nation whose economy is underpinned by a disproportionately high reliance on the primary industries, typically seen in countries of lower socio-economic levels. New Zealand therefore has DRM options and opportunities not necessarily available to other nations with similarly high levels of reliance on their rural sector.

These objectives are accomplished using two case studies. The first examines disaster impacts and response and recovery actions following the 2016 'Kaikōura' earthquake to explore the underlying drivers of disaster risk in rural New Zealand. The second focuses on Project AF8, a cross-jurisdictional and multi-agency initiative to plan and prepare for a coordinated response following a large magnitude earthquake along the Alpine Fault on New Zealand's South Island. Results from the Kaikōura earthquake case study reveal a sophisticated network

of interdependent systems, including critical infrastructure (lifelines), social networks, value chains, institutional coordination, and governance arrangements. The impacts of this multi-hazard event are complex in time and space, and compounded by a pre-existing, highly stressed region from a multi-year drought. Secondary effects resulting from the earthquake ground motion (such as isolation) were found to be important local drivers of disaster risk. The results show a need for improved coordination and application of impact assessments by responding agencies and to increase understanding of the issues likely experienced in rural regions following a disaster. The study found strong elements of community resilience, but results highlight a need for a holistically coordinated organisational sector. Ultimately, the findings suggest rural DRM is most likely be most effective when driven by rural perspectives.

The second case study analyses methodologies used by Project AF8 to plan and prepare for a coordinated response to a large magnitude earthquake along the Alpine Fault, one of New Zealand's major natural hazard risks. The Project AF8 process of generating, sharing, and using multi-disciplinary disaster risk information within a 'co-creation' collaboration involving both practitioners and scientists is analysed. This allows for the identification and investigation of what decision-makers within New Zealand institutional and social structures may need to more effectively address rural DRM planning. Results show that while the content of disaster risk information is important to emergency management practitioners, the process which manages the creation of the disaster risk information content is equally important.

The findings from this thesis are informed by perspectives from pre-event planning, syn-event response operations, and post-event recovery activities relating to rural earthquakes, allowing examination of the broader systematic issues within rural DRM in the New Zealand context. The learnings and recommendations presented here have implications for enhancing rural DRM and resilience in developed economies and provide high-level strategic guidance for other large interdisciplinary initiatives centred around the research-practice interface, particularly those dealing with disaster risk reduction and emergency management. As a whole, this work contributes to a greater understanding of the vulnerabilities and capacities of rural regions to disasters, and generates new insight and empirical evidence addressing rural DRM in high-income nations.

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Rural impacts of New Zealand's 14 November 2016 'Kaikōura' earthquake (Chapter Two).
Prepared and intended for submission to: Resilience to Nature's Challenges Technical Report

The manuscript was prepared and written by Tyler Barton, who also conducted the interviews, coded and analysed the interview data, performed the geospatial impact assessment, and interpreted the results. The concept of the manuscript was developed through discussion between Tyler Barton, Prof. Thomas Wilson, Dr. Sarah Beaven, and Dr. Nicholas Cradock-Henry. Dr. Beaven provided additional guidance and support for interview methodology, questions, and data processing. Prof. Wilson, Dr. Beaven, and Dr. Cradock-Henry all contributed to refining and developing the manuscript, including through draft revisions.

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Chapter One – Introduction

1.1. Background to research project

Extreme geophysical and hydro-meteorological hazards can have substantial consequences for rural areas through impacts to distributed critical infrastructure networks, rural value-chains, primary production (e.g. crops and livestock), local ecosystems, communities, and more (World Bank, 2006; Smith et al., 2011; World Bank, 2013; Murphy et al., 2014; GFDRR, 2016; Aydin et al., 2018; IPCC, 2019; Pearce et al., 2020). While definitions vary, rural areas are typically characterised as non-urban regions with low population densities (UN, 2019). However, population density alone does not necessarily reflect the characteristics that make places similar, or not, and this classification scheme has been recognised as inadequate for differentiating between the broad range of communities and regions that exist outside of urban centres (Hathout, 2002; Statistics New Zealand, 2020a). This is reflected by multiple international efforts at using additional characteristics (such as land-use) to refine the distinction between urban and rural contexts (Teljeur and Kelly, 2008; Cochrane and Maré, 2017). Therefore this work adopts a definition of 'rural' that is determined by comparing residential and workplace addresses for employed populations, and are categorised by the New Zealand government as "highly rural / remote areas" and "rural areas with low urban influence" (Statistics New Zealand, 2004a; Statistics New Zealand, 2004b). This acknowledges the difference between areas dominated by resource-based livelihoods (considered rural) and communities where a large proportion of the population commutes to urban areas for work but happen to live in a small satellite community (not considered rural) (Statistics New Zealand, 2020a). This dependence on the natural environment means rural communities and economies can have high exposure to natural hazards and can be uniquely vulnerable to the effects of disasters, such as earthquakes, floods, and droughts (World Bank, 2006; Chapagain and Raizada, 2017; Lloyd and Hales, 2019).

To reduce these adverse effects, there is a considerable body of research and practice aimed at disaster risk reduction (DRR), defined as "preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience" (UNDRR, 2017). Resilience here refers to "the ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the

effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management*"* (UNDRR, 2017). The application of DRR policies and strategies to enhance disaster resilience is the objective of disaster risk management (DRM), which, by definition, aims to "prevent new disaster risk, reduce existing disaster risk, and manage residual risk" (UNDRR, 2017).

Over the past 50 years, considerable progress has been made globally in recognising the underlying drivers of disaster risk (Wisner, 1995; Cardona et al., 2012; Djalante, 2013; UNDRR, 2015a; Oliver-Smith, 2016; IPCC, 2019). Much of the research on rural DRM has been focused on low-income nations, driven by high disaster exposure and vulnerabilities which has led to disproportionally high impacts in those countries (World Bank, 2006; World Bank, 2013; Shameem, 2014; Imai et al., 2017). There is comparatively less rural DRM research in high-income nations, where studies have focused primarily on rural development (i.e. urbanisation) and agricultural extension (i.e. technologies and advanced techniques to optimise farm yields) (Pelling, 2003; Bankoff et al., 2004; Wall and Marzall, 2006; Spector et al., 2018; McKay et al., 2019). However, rural impacts in high-income nations can still be severe, as evidenced by the $5 billion USD losses to the timber industry alone in the USA following Hurricane Katrina (Sheikh, 2005). While other issue-based fields align with aspects of DRM by helping rural communities and environments cope with the negative impacts of ecosystem decline, vulnerable livelihoods, population growth, climate change, and other drivers of disaster risk (UNDRR, 2009; Gentle and Maraseni, 2012; Islam et al., 2014; Oliver-Smith, 2016), there is an urgent need for targeted, applied research to address critical empirical and knowledge gaps for informing effective rural DRM policy and practice in high-income nations.

1.2. Research aims and objectives

This thesis examines the rural impacts of natural hazards and pre- and post-event strategies for reducing and managing disaster risk in a high-income nation, using New Zealand as a case study. New Zealand provides a rich empirical context for examining this topic due to its economic dependence on primary industries, and the social and cultural significance of rural regions (MCDEM, 2007; Conradson and Pawson, 2009; Spector et al., 2019).

There are three objectives:

1. Identify the key drivers of disaster risk in rural New Zealand;
2. Map the institutional and social structures that inform, enable, and constrain DRM decision-making in rural New Zealand in response to those drivers; and
3. Identify opportunities to enhance effectiveness of rural DRM in New Zealand.

To answer these research objectives, a mixed methods approach is used, drawing insights from natural and social sciences. It employs participatory research methods (semi-structured interviews, a focus group, and participant observation) to identify relevant drivers of rural disaster risk in New Zealand. Quantitative geospatial analysis complements the qualitative analysis. The thesis makes an empirical contribution to the field of rural DRM through a broad examination of rural DRM in New Zealand, focused on systematic opportunities and challenges. It analyses the vulnerabilities and capacities of the rural DRM sector through the lens of both a pre-disaster initiative for risk reduction (Project AF8), and post-disaster response and recovery following a major disaster (2016 Kaikōura earthquake). Finally, this work also investigates how knowledge is developed and used in a rural DRM context with a focus on co-creation methodologies as an opportunity to enhance rural DRM. While this work has an applied focus, it is informed by, and contributes to, global theory in other fields of research that address similarly complex global social issues. Results provide a pathway and resource for those considering or preparing to engage in less traditional approaches to both decision making (i.e. collaborative governance) and the use of science (i.e. the science-practice-policy interface) in rural DRM.

The remainder of this chapter is organised as follows: first, key definitions and conceptual relationships are summarised. Next, a review of global disaster trends and international commitments to DRM is presented. Then, attention is drawn to two key challenges in achieving effective rural DRM. First, is the need to adopt a rural perspective when considering DRM in rural areas in order to better understand the underlying causes and drivers of local disaster risk. Second, is the need for the use of collaborative decision-making in rural DRM in order to ensure initiatives are tailored for the relevant area. This is followed by an overview of rural DRM in the New Zealand case study, presentation of the research methodology, and finally an overview of the structure and sequence of the thesis chapters.

1.3. Key definitions

The United Nations Office for Disaster Risk Reduction (UNDRR) considers *disaster risk* to be "determined probabilistically as a function of hazard, exposure, vulnerability, and capacity" (UNDRR, 2016). It also defines *hazard* as a process, phenomenon, or human activity that may cause loss of life, injury, or other health impacts, property damage, social and economic disruption, or environmental degradation; *exposure* as the location of people, infrastructure, and assets in hazard-prone areas; *vulnerability* as the combined physical, social, economic, and environmental factors which increase the susceptibility of hazard impacts; and *capacity* as the combination of all strengths, attributes, and resources available to manage and reduce disaster risks and strengthen resilience (UNDRR, 2016). While a high probability of a hazard coupled with high levels of exposure and vulnerability would increase disaster risk, a high level of capacity would lower it. The conceptual relationship between these factors is:

$$Disaster\ risk = \ Probability\ of\ a\ hazard \times \frac{Exposure \times Vulnerability}{Capacity} \qquad (1)$$

The UNDRR also defines *disaster impacts* as "the total effect" of a hazardous event (UNDRR, 2016). High exposure and high vulnerability of an individual, community, organisation, assets, or infrastructure will increase the potential level of impact from natural hazards, while a high adaptive capacity will lower the potential level of impact. The conceptual relationship between impact, exposure, vulnerability, and capacity is:

$$Disaster\ impacts = \frac{Exposure \times Vulnerability}{Capacity} \qquad (2)$$

Therefore, combining these two theoretical relationships, we can consider disaster risk to be a function of the likelihood of an event occurring (i.e. the probability) and the overall possible consequences in which this may result (i.e. impact):

$$Disaster\ risk = \ Probability\ of\ a\ hazard \times Potential\ impacts \qquad (3)$$

1.4. Research context

A key global objective for DRM is reducing disaster fatalities, yet data trends, and a weight of associated research, clearly indicate that current efforts are struggling to reduce impacts to well-being, livelihoods, and economies (Gall et al., 2011; Guha-Sapir et al., 2014; Cutter et al., 2015; UNDRR, 2015a; CRED, 2020). These data trends (Figure 1.1), indicate that overall disaster impacts to society (Figure 1.1c) and economies (Figure 1.1d) may even be increasing, though it is important to note that other factors may be influencing these trends, such as better contemporary reporting and exposure of newer and more expensive assets. With the frequency and intensity of natural hazards expected to increase in the future due to climate change, population growth, eco-system degradation, and other disaster risk drivers, global exposure and vulnerability to disasters is set to rise (World Bank, 2006; Gall et al., 2011; World Bank, 2013; Mechler and Bower, 2015; Grant et al., 2015; GFDRR, 2016; IPCC, 2019).

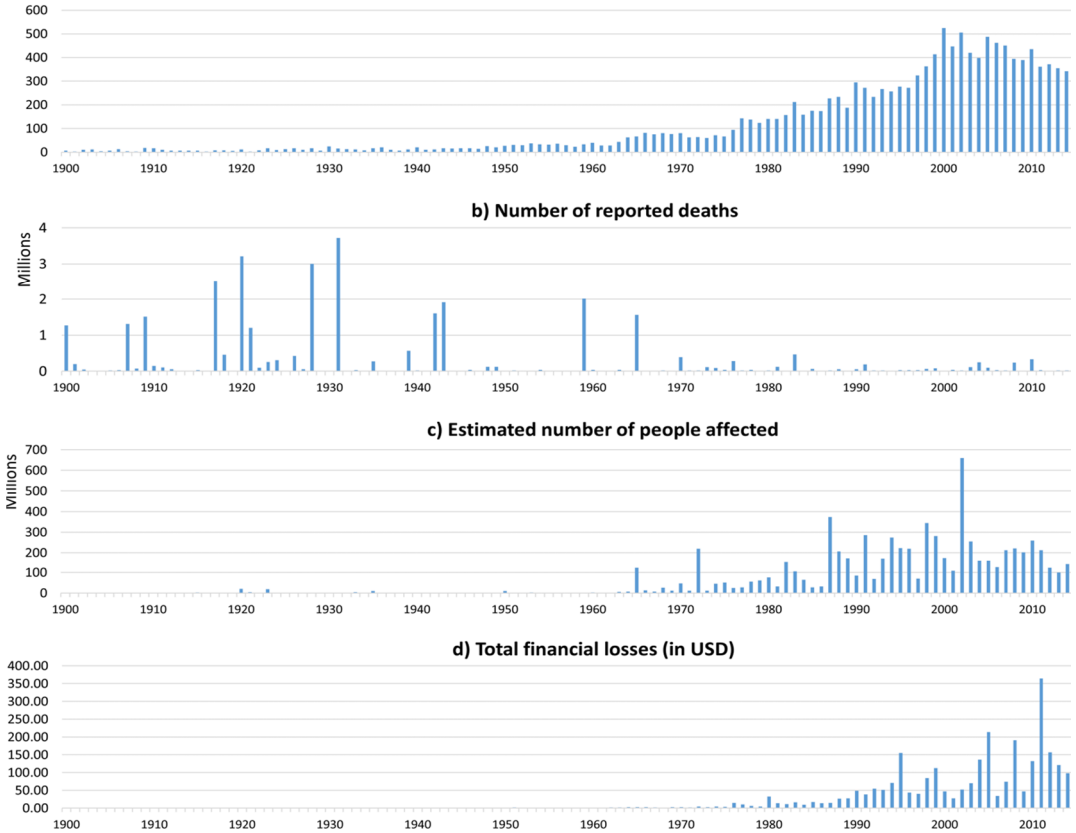

Figure 1.1 Global disaster data from 1900 - 2019 indicating a) the number of disaster events recorded, b) the number of reported deaths directly attributed to disasters, c) the estimated number of people affected, and d) the approximate financial losses caused by disasters. Data from CRED (2020).

1.4.1. Global approaches to reducing disaster losses and increasing disaster resilience

In order to reduce losses from disasters, policy-makers, researchers, and practitioners have called for greater attention to the need to enhance disaster resilience through more effective DRM practices (Paton and Johnston, 2017; Tiernan et al., 2019). The United Nations General Assembly recognised the need for international cooperation in the field of DRR and designated the 1990s as the 'International Decade for Natural Disaster Reduction' (UN General Assembly, 1989). An approach to DRM that focused on 'risk reduction' was designated worldwide best practice in 1994 at the First World Conference on Natural Disasters in Yokohama, Japan, where an official strategy was put forward that recognized the need for the proactive reduction of risk and focused on decreasing vulnerability (UN, 1994). When this international strategy was formalised and released in 2005 as the Hyogo Framework for Action 2005 – 2015, decreasing vulnerability was framed as one measure, among others, of the overarching strategic goal to build disaster resilience (UNDRR, 2005; Fekete et al., 2014). This shift in DRM focus was continued with a strengthened emphasis on the concept of resilience included in the Sendai Framework for Disaster Risk Reduction 2015 – 2030 (SFDRR), successor to the Hyogo Framework for Action 2005 – 2015 (UNDRR, 2015a). International commitments to disaster risk reduction through time are shown in Figure 1.2.

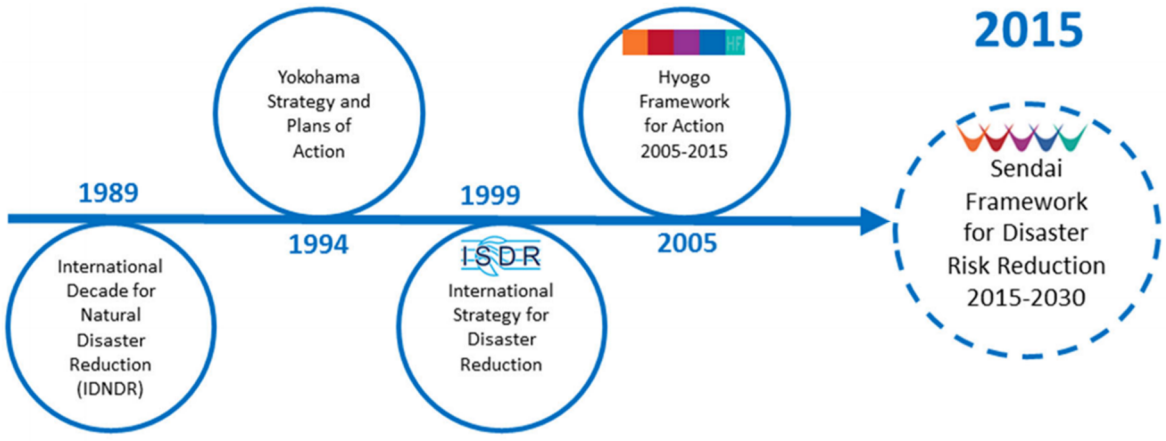

Figure 1.2 International commitments to disaster risk reduction (from Aitsi-Selmi et al., 2015).

The purpose of the SFDRR is to outline a framework of guiding principles and priorities addressed to governments and others involved in DRM (UNDRR, 2015a). It aims to facilitate

the disaster risk reduction required to build resilience by targeting four priority areas for action (UNDRR, 2015a). Rural disaster resilience is only specified, however, under Priority 3 (Investing in Disaster Risk Reduction for Resilience), which includes the need:

- *to promote mechanisms for disaster risk transfer and insurance (…) to reduce the financial impact of disasters (…) in urban and rural areas* (UNDRR, 2015a, section 30b, page 19); and
- *to promote the mainstreaming of disaster risk assessment, mapping and management into rural development planning and management* (UNDRR, 2015a, section 30g, page 19).

Despite the SFDRR intention to be globally applicable, there is little mention of rural-specific DRM. Although DRM specific to rural areas is alluded to outside of the excerpts mentioned earlier (such as section 19e, on page 13, and section 24i, on page 15 of the document), it is not specifically differentiated from DRM intended for use in urban areas. The greater emphasis on urban DRM and absence of specific references to the distinction between 'urban' and 'rural' in the SFDRR document may reflect a broader tendency in the wider DRM field to focus on policies and practices which are fit-for-purpose in urban centres rather than rural regions (World Bank, 2006; Rivera and Kapucu, 2015; Cutter et al., 2016).

1.4.2. Rural disaster risk: needs, priorities, perspectives

The specific needs, priorities, and issues for rural DRM however, are distinct from those of urban areas (Eakin et al., 2008; Boon, 2014; De et al., 2014; Cradock-Henry et al., 2018; Fang et al., 2018; McKay et al., 2019). Previous global reports on disasters in rural regions have found they are primarily driven by poor land-use planning, ecosystem decline, and vulnerable livelihoods (UNDRR, 2009; OECD, 2012; World Bank, 2013; GFDRR, 2016). All of these are complex topics with multiple contributing factors, often unique to each location. To contextualise the thesis research, this section briefly reviews the literature on rural resilience as applied to DRM.

Unplanned and poorly regulated development patterns in rural areas, such as infrastructure and settlements built in low-lying coastal areas or on flood plains, represent a rising concentration of population and assets situated in highly exposed and vulnerable areas (IPCC, 2012; Islam et al., 2013; World Bank, 2013; Islam et al., 2014; Mechler and Bouwer,

2015; IPCC, 2019). While the financial losses to high-income nations are generally greater due to higher net worth of impacted infrastructure and assets, the impact to low-income nations relative to their national wealth is usually more severe (World Bank, 2013). A key issue is the growing exposure of humans, livelihoods, and the built environment to hydro-meteorological hazards (such as droughts, storms, and floods), which is likely to continue given the expected increase in frequency and magnitude of these events driven by climate change (IPCC, 2014). While geophysical events (such as earthquakes, landslides, volcanoes, and tsunamis) are expected to continue occurring at current rates, increasing exposure to these events, primarily due to population growth, means that disaster risk also continues to increase (GFDRR, 2016).

Furthermore, the ongoing degradation of ecosystems reduces the capacity of rural communities and areas to cope with the impacts of natural hazards and provide for basic needs (such as water, food, and shelter) before, during, and after a disaster (Joerin et al., 2012; Renaud et al. 2013; Tanner et al., 2015; Rakotobe et al., 2016). The effects of climate change are directly contributing to changes in both global and local ecosystems, as rising global temperatures, shifting rainfall patterns, and elevated sea levels are changing ecological norms in both low- and high-income nations (IPCC, 2012; World Bank, 2013; IPCC, 2019). Existing delicate ecological balances are further stressed by an increasing demand for global food and livestock feed attributed to rising population growth (IPCC, 2019). An increasing number of humans are relying on finite ecological resources such as food, water, minerals, and wood, and this has contributed to cases of extreme resource competition, particularly in low-income nations (Cuba et al., 2014; Ratner et al., 2018). This issue can contribute to further ecosystem decline, as efforts to increase productivity and yields in rural areas have resulted in the use of intensive farming techniques and machinery, especially in high-income nations, placing an additional burden on the natural environment (OECD, 2012).

Efforts to increase rural productivity have, in turn, increased economic vulnerability to the effects of natural hazards (World Bank, 2006; Alfani et al., 2019). For example, the use of expensive specialised machinery or highly engineered and sophisticated irrigation schemes likely require specialist expertise and parts to repair, which may not be possible to obtain immediately following a disaster (Duque and Sorenson, 2011; Duque et al, 2016). Additionally, rural livelihoods and businesses are increasingly at risk of isolation, given trends for cost-effective centralisation of agribusiness processing services (Johnson, 2001; Marin et al., 2015) and a rural based tourism industry which encourages a broad range of outdoor activities (from

scenic touring and hiking to skiing and white water rafting) in remote areas (Bentley et al., 2001; McKay et al., 2019). A disruption that affects these long, distributed infrastructure networks upon which rural economies depend can result in impacts to globalised rural sector value chains, breaks in business continuity, and displaced tourists and residents (World Bank, 2006; OECD, 2012; Ye and Abe, 2012).

Another global challenge to rural DRM efforts and driver of disaster risk is poverty (Thomalla et al., 2006; Gentle and Maraseni, 2012; Winsemius et al., 2015). The poorest populations and most marginalised communities commonly live in highly exposed areas and in vulnerable conditions (Krishna et al., 2018); these groups are more vulnerable to disaster impacts than most (World Bank, 2013). Those living in poverty have been observed to also be the least able to recover from disasters, which can have crippling short and long-term effects on livelihoods (Carter et al., 2008; World Bank, 2013).

An additional driver of disaster risk in rural areas, and a challenge to effective DRM, is the rapid pace at which rural economies and livelihoods are changing and evolving (Smith and Montgomery, 2004; Perkins et al., 2015; McKay et al., 2019). Increased use of technology, especially in high-income nations, may have resulted in increased agricultural yields and automation of certain agricultural tasks, but has correspondingly increased the exposure of expensive and sophisticated machinery and irrigation systems to natural hazards in rural areas (Cook, 2011). The decentralisation of rural services has increased reliance on a highly distributed infrastructure network, which has in turn increased the exposure and vulnerability of rural supply chains (UN, 2006; Perks et al., 2009; Smith et al., 2011). Farm income, and thus many farmer production and lifestyle decisions, are often highly influenced by global markets and the ability to access these markets; even smaller subsistence farms require access to local, regional, and international markets if they are to develop, grow, and thrive (World Bank, 2013).

However, there is comparatively limited scientific knowledge on rural disaster risk and risk management on which to base rural DRM policy and practice in high-income nations. Rural DRM in high-income nations faces challenges due to the shifting drivers of rural disaster risk, rising levels of exposure and vulnerability, the rural application of DRM practices fit-for-purpose in urban areas, a lack of scholarship on rural disaster impacts, and a tendency to use decision-making frameworks that may not be robust enough to the address these types of large complex social issues (World Bank, 2006; Wilson et al., 2007; Hallegatte and Dumas, 2009; Cavallo and Noy, 2009).

1.4.3. Collaborative decision making for rural disaster risk management

Another equally critical issue for rural DRM is the need for strategies that enable and support more collaborative approaches to building DRM knowledge for making and implementing decision-making. This need is one of the key 'lessons learned, gaps identified and future challenges' that has emerged from the Hyogo Framework for Action 2005 – 2015 (and subsequently been incorporated into the SFDRR), which states:

> There has to be a broader and a more people-centred preventive approach to disaster risk. Disaster risk reduction practices need to be multi-hazard and multisectoral, inclusive and accessible in order to be efficient and effective. While recognizing their leading, regulatory and coordination role, Governments should engage with relevant stakeholders, including women, children and youth, persons with disabilities, poor people, migrants, indigenous peoples, volunteers, the community of practitioners and older persons in the design and implementation of, plans and standards. There is a need for the public and private sectors and civil society organizations, as well as academia and scientific and research institutions, to work more closely together and to create opportunities for collaboration, and for businesses to integrate disaster risk into their management practices. (SFDRR, Preamble, section 7, page 10)

Although it is well recognised that multiple agencies, organizations, and governments must work together to achieve mutual understanding and commonly set goals, this can be difficult to achieve, since it requires increased integration between national, regional, and local levels, and between sectors (Waugh and Streib, 2006; Termeer et al., 2011; Brummel et al., 2012; Weiss et al., 2012; Wyborn et al., 2017). Poor implementation of management strategies at the local level has been identified as a hurdle to effective DRM (Jordan, 1999; IFRC, 2014). This can, in part, be attributed to a shift in responsibility for risk reduction decision-making over the past two decades, as "top-down" styles of risk management begin to give way to "bottom-up" approaches. This has shifted much of the responsibility for DRM implementation from government authorities (top-down) to individuals, communities, and private organizations (bottom-up) (Scolobig et al., 2015). This transfer of responsibility for DRM decision-making does not always involve the transfer of resources, knowledge, and willingness required to implement DRM measures, and often lacks mechanisms to ensure it is effectively accomplished, which can lead to poor implementation of DRM legislation.

A recent critique of New Zealand's disaster risk policies found shortcomings in how disaster risk is identified and managed in the New Zealand context, which would benefit from

national and regional coordination platforms (Basher, 2016). These findings are in line with emerging literature in the wider field of DRM, which applies concepts and frameworks from other issues-based fields to analyse existing collaborative DRM initiatives and have identified the need for similar collaborations in other contexts (Thomalla and Larsen, 2010; Djalante and Thomalla, 2011; Aoki, 2016; Beaven et al., 2017; Aoki, 2018).

These contributions provide limited evidence that collaborative approaches to decision-making have proven effective in the broader (i.e. not specifically rural) DRM context. Furthermore, these contributions draw from a much larger body of evidence, including empirical case studies from diverse fields such as environmental management, climate change adaptation, sustainability, and conservation (Mauser et al., 2013; Wood et al., 2015; Wyborn et al., 2017). This literature shows that co-creation methodologies are effective at bringing together scientists, practitioners, policy makers, and communities to explore problems together and develop both theoretical and practical solutions (UNDP, 2010; Mauser et al., 2013; Frow et al., 2015; Wood et al., 2015; Karpouzoglou et al., 2016; Wyborn et al., 2017; UNFAO, 2020). While there is some scholarship regarding the use of collaborative approaches to rural DRM (Thomalla and Larson, 2010; Thompson et al., 2015; Aoki, 2018), it is not yet commonly applied, especially in high-income nations.

1.4.4. Rural disaster risk management informed by other fields of research

Policies and practice from other topic areas, which may not specifically consider disasters and risk management, may be informally and indirectly driving DRM in rural areas. Environmental Management and Sustainability fields, for example, aim to maintain and improve the state of natural resources affected by human activities, and the outcomes of initiatives driven by these aims can include increased disaster resilience (Pahl-Wostl, 2007). As the drivers and consequences of environmental degradation are often complex, uncertain, multi-scale, and can affect multiple actors and organisations (Reed, 2008), the field of Environmental Management has had to find new pathways forward to handle this complex mix of social and ecological issues (World Bank, 2006). Environmental Management and rural DRM both deal with highly contentious issues (such as climate change) and decisions (such as land use planning). Lessons learned from the Environmental Management discipline are relevant to the rural DRM context as they can help understand the resilience of natural environments to

external shocks and stressors. There is a wealth of evidence in the field of Environmental Management that stakeholder participation in the decision-making and governance processes can substantially enhance the trust, buy-in, and quality of environmental management decisions by considering a more comprehensive range of perspectives and knowledge (Stringer et al., 2007; Reed, 2008, and references therein; Bruges and Smith, 2008; Bautista et al., 2017; Hewitt and Macleod, 2017; Luhrs et al., 2018). As the fields of Environmental Management and rural DRM share an overlapping need to safeguard the natural environment from the negative impacts of natural hazards, it can be useful for the approaches used by Environmental Management to inform rural DRM.

Another field which can help inform understanding of rural disaster resilience and DRM is Development Studies, which addresses aspects of economic and social resilience. Many Development Studies are concerned with social change and poverty in low-income nations, and commonly have a focus on rural regions, home to approximately 75% of the global population living below the international poverty line of $1.25 USD per day (UNDRR, 2009; De la O Campos et al., 2018). Some development studies do, however, focus on urbanisation and extreme poverty in urban settings (Ravallion et al., 2007; Yap and Mcfarlane, 2019). Much global development research, practice, and policy is guided by the Sustainable Development Goals, an integrated agenda for both low- and high-income nations that sets goals, targets, and indicators to address "poverty, inequality, climate change, environment degradation, peace and justice" (UN, 2020). There is a shared agenda between many of the Sustainable Development Goals and the SFDRR, in that both aim to increase economic and social resilience in rural regions, which would enhance the ability of these regions to absorb and accommodate the negative impacts of hazards. Increasing the economic and social aspects of resilience aligns with the rural DRM aim to increase disaster resilience. However, this is a nuanced issue, as, in some cases, global development efforts can run diametrically opposed to rural DRM efforts. For example, local or regional policies geared towards community development may actively encourage deforestation for agricultural purposes, but this boost to local economies might result in increased exposure to landslides if in hilly terrain (Caine and Mool, 1982).

Furthermore, Climate Change Adaptation (CCA) represents a series of policy and practice efforts aimed at addressing climate-related risks, using proactive and anticipatory actions to reduce climate risk at different time scales (Velasquez and Tran, 2010). As climatic conditions directly impact natural resource-based activities, rural businesses, and by extension

communities, rural way of life is particularly sensitive and vulnerable to climate change (Hales et al., 2014; Cradock-Henry et al., 2020). A holistic and collaborative approach to policy and practice in rural areas has been found necessary to best address CCA challenges (OECD, 2012), and could benefit the field of rural DRM.

Like rural DRM, these fields are all focused on highly complex social issues that can vary in scale, be highly uncertain, and can affect multiple actors and organisations. They have established that complex situations are usually best addressed by ensuring that a range of people, perspectives, and knowledge are brought into decision-making, in a number of different ways (Reed, 2008; OECD, 2012; Mauser et al., 2013; World Bank, 2013; Fraw et al., 2015; Wood et al., 2015; Haworth et al., 2016; Wyborn et al., 2017). This focus on the need to enhance collaborative decision-making approaches and bring together cross-sector groups has the potential to help inform best-practice for rural DRM (Djalante et al., 2011; Thompson et al., 2015). Another unifying thread between these topics and DRM is that, while policy and practice efforts must ultimately be guided by national policy, implementation efforts need to consider local priorities and contextual differences with respect to key aspects of community (UNFCCC, 2008; IFRC, 2009). Perhaps most notably, the overarching lessons these fields have to offer to the field of rural DRM are that it is important to think about who makes the decisions, how to share this decision-making process, and that more inclusive approaches to knowledge building and decision-making have had considerable success.

Given the aligned aims and occasionally overlapping agendas between these fields and the field of rural DRM, lessons identified and learned can be applied to, and benefit, rural DRM. This thesis does not engage directly with the issues or theoretical debates that are central to these other issue-based fields. It does however draw from broader concepts and findings, particularly those from Development Studies (Woolcock, 1998; Sofield and Li, 2011) and CCA work (Birkmann and von Teichman, 2010; Solecki et al., 2011) concerning the evidence-base establishing the need for more collaborative, distributed approaches to knowledge generation and decision-making, which Djalante and Thomalla (2011) find to be particularly applicable in rural areas after disasters.

1.5. Overview of the case study: rural disaster risk management in New Zealand

This thesis will use New Zealand based case studies to address the lack of scientific knowledge regarding rural DRM in high-income nations, as rural regions in that country provide substantive contributions to the national economy and society. Overall, the primary sector (agriculture, horticulture, forestry, mining, and fisheries) accounts for 6% of New Zealand's gross domestic product (GDP), and contributes to over 50% of total export earnings (New Zealand Treasury, 2016). Flow-on effects from the primary sector (such as processing, manufacturing and rural transport businesses) account for an additional 17% of GDP (MCDEM, 2007). Tourism, which accounts for a further 5.8% of annual GDP (Statistics New Zealand, 2020b), also relies on the natural environment, particularly the picturesque scenery and range of outdoor activities it offers.

New Zealand also offers insights into the unique disaster resilience advantages and challenges faced by a high-income nation with an economy underpinned by the disproportionately high reliance on the primary industries that is more typical of countries with lower socio-economic status (Kamber et al., 2013). DRM in New Zealand is facilitated and enabled by:

- A robust national level response and recovery legislation (IFRC, 2014);
- Modern government with low levels of corruption (OECD, 2019);
- Strong social welfare support and health care systems (OECD, 2019);
- Low levels of impoverishment (OECD, 2020);
- Stable currency and financial markets (Bedford, 2008);
- High construction standards for infrastructure and strong building regulations, which are regularly enforced (MCDEM, 2007; Buckett, 2014);
- High levels of insurance and other disaster-risk transfer mechanisms (Insurance Council of New Zealand, 2020; Nguyen and Noy, 2020); and
- A strong cadre of highly trained emergency management professionals (IFRC, 2014).

From a governance perspective, New Zealand aligns with international best practice and has been considered a world-leader in national level DRM legislation (IFRC, 2014; Saunders et al., 2020). The government has adopted a 'whole of society' approach to align with and implement the SFDRR (UNDRR, 2015b). The DRM goals of the New Zealand government in relation to achieving disaster resilience are outlined in the National Disaster Resilience Strategy

(MCDEM, 2019), which also includes objectives to be pursued by government agencies (note that the National Disaster Resilience Strategy was not yet published until after the research, analysis, and most of the write-up phases of this thesis). The objectives of this resilience strategy include managing disaster risks, enabling effective response and recovery, and empowering community resilience (MCDEM, 2019). However, New Zealand's DRM legislation has been recently criticised for lacking legislative and regulatory mechanisms to coordinate DRM efforts, such as a national platform for disaster risk reduction, which is promoted by both the Hyogo Framework for Action 2005 – 2015 and the SFDRR. Instead, New Zealand "governance of [disaster] risk is spread across many acts, and risk management is spread across many departments and levels of government, without obvious integration" (Basher, 2016).

New Zealand also aligns with international best practice in that the work of national practitioners and policy experts is well supported by a strong natural hazard and disaster risk research sector, facilitating evidence-based risk reduction and DRM throughout the country (Leonard and Potter, 2015; MacAskill and Guthrie, 2016). However it is important to note that, for the most part, much of this scholarship remains uninformed by the collaborative decision-making approaches that are now widespread in other fields (World Bank, 2013). Studies characterising resilience to natural hazards in a rural New Zealand context are mostly qualitative in nature and address a limited number of topics and locations (Spector et al., 2019, and citations therein). As Spector et al. (2019) point out, the better addressed research topics within rural DRM in New Zealand, though still limited in number, include research on farm level preparedness (e.g. Smith et al., 2011), community engagement (e.g. Johnston et al., 2012), community resilience (e.g. Paton et al., 2001), and organisational resilience (e.g. Whitman et al., 2013).

As an application of research approaches more widely used in other topic areas, the research articulated in this thesis helps to reduce the gap in the literature identified globally (World Bank, 2013) and within New Zealand (Spector et al., 2019) by providing an empirical study of rural DRM in a high-income nation, and increasing the evidence base for the use of collaborative approaches to rural DRM decision-making. It consists of two case studies. The first is concerned with what the response and recovery to the 14 November 2016 'Kaikōura' earthquake reveals about the impacts and cascading effects of a large, complex earthquake with multiple co-seismic hazards on rural New Zealand. The impacts to the rural sector are

investigated, as well as what this reveals about the need for more collaborative governance in rural DRM. This work uses a holistic approach to studying rural areas by considering how disasters and social issues affect a patchwork of different people, organisations, and communities. The second case study is the Project AF8 initiative, a co-creative multi-stage preparedness project that incorporates scientific modelling, response planning, and community engagement into sector-wide preparation for a magnitude 8.0 earthquake along the Alpine Fault, which spans predominantly rural areas of New Zealand's South Island. Following collaborations between emergency managers and researchers, the jointly generated knowledge from Project AF8 is then shared with the wider populations and communities. A critical analysis of the co-creation methodologies used by Project AF8 to drive DRM decision-making occurs, including the non-traditional approaches used to address the science-practice-policy interface in the rural context.

1.6. Research methodology

This thesis uses mixed-methods to explore disaster impacts and risk management in rural New Zealand, with a focus on the South Island, and North Canterbury in particular. This section provides an overview of thesis research methods; each following chapter provides details of the methods used for the research.

For the 2016 Kaikōura earthquake case study (Chapters 2 and 3), geospatial analysis is used to quantitatively assess the exposure of rural properties on the South Island to ground motion during the event. This is supplemented with targeted interviews of local and external response and recovery actors involved in rural DRM in general, and the Kaikōura earthquake in particular. Participants included full and part-time emergency managers and disaster risk managers from government and non-government organisations, from both policy and practice domains active at local, regional, and national levels. Given the complex and multi-faceted nature of the social issues explored as part of this study, semi-structured interviews were used (Mason, 2002; Patton, 2002). Interviews solicited information on professional experiences and personal learnings from the event. Interview data was collected between September 2017 and August 2018. Interview transcripts were manually and iteratively coded with spreadsheet software, using an inductive framework analysis as described by Thomas (2006). Themes related to rural vulnerability, organisational interfacing, and response coordination were first

identified by the lead author, then discussed amongst all authors. Transcription and analysis was supplemented with additional insights obtained from peer-reviewed academic journals and 'grey' literature (such as government reports, policy documents, and emergency management newsletters). The combination of qualitative interview data and quantitative geospatial analysis of the region contribute to a wider picture of disaster impacts, response, and recovery to rural New Zealand following the Kaikōura earthquake.

For the Project AF8 case study (Chapter 4), interviews, a focus group, document analysis, and participant observation were used to gain insight into the effectiveness and performance of the approach used to generate knowledge for DRM. The interview participant selection process, timing, and data analysis were conducted as described above. Open-ended questions were designed to gauge perceptions of the extent to which co-produced disaster risk knowledge from the Project AF8 initiative was perceived to be scientifically credible and also relevant enough to be used by practitioners and policy makers in day-to-day tasks. Questions for practitioners and policy makers also focused on the application and performance of Project AF8-generated material at different levels and in different roles (such as council employees within local and regional government). A focus group was conducted with Project AF8 leaders, consisting of senior level emergency managers and the project's lead scientist. The focus group discussion addressed questions similar to those used in interviews. Participant observation included author involvement in the early development of the initial Project AF8 workshop, as well as attendance, observation, note taking, and in some cases active participation in a selection of subsequent meetings. This review of the process used to generate DRM knowledge during Project AF8 provides insight and lessons on how collaborative decision-making might be used in future rural DRM efforts within New Zealand.

All interview guides, protocols and questionnaires were subject to peer review. Ethical review and approval for this research project was obtained from the University of Canterbury's Human Ethics Committee (reference number: HEC 2017/34/LR-PS).

1.7. Thesis structure

The thesis is organised by presenting an introduction (Chapter 1) which is then followed by three research chapters comprising manuscripts that, at the time of writing, have either been

accepted for publication in an academic journal (Chapter 4), or are intended for submission to academic journals (Chapters 2 and 3) shortly thereafter.

- Chapter 2 consists of an impact assessment of rural North Canterbury following the 2016 Kaikōura earthquake, aftershock sequence, and associated co-seismic hazards. This analysis focuses on the 12 months following the event, to better understand what can happen to rural communities (mostly involved in primary production) in a high-income nation following a large earthquake. This chapter serves to illustrate **what** happens when a complex earthquake with multiple co-seismic hazards affects rural New Zealand, **how** rural DRM responds, and begins to look at **who** is and might be involved in rural New Zealand disaster response and recovery.
- Chapter 3 argues the need for rural perspectives to drive rural DRM. While the previous chapter identified and documented the range of impacts and challenges experienced by rural sectors and communities following the earthquake, this chapter investigates **why** these may have occurred. One of the main issues identified in Chapter 2 was a lack of integration of rural needs and priorities into the official government response mechanism. This chapter considers the perspectives of both rural and non-rural actors involved in the Kaikōura earthquake response and recovery (i.e. the '**who**') to better understand this interface.
- Chapter 4, the final core chapter of this thesis, is centred around knowledge sharing in interdisciplinary DRM initiatives. This chapter builds on the previous thesis chapters by considering **how** rural perspectives can best inform and be included in DRM practice and policy. This chapter focuses on a pre-event planning initiative to examine the process of generating, sharing, and using multi-disciplinary disaster risk knowledge within a 'co-creation' collaboration involving both scientists and DRM practitioners. It does this by investigating the non-traditional framework used by Project AF8 to co-create disaster risk knowledge, enhance collaborative governance, and improve the science-practice-policy interface as a means to investigate ways in which rural DRM efforts may be enhanced moving forward.

The thesis concludes with Chapter 5, which summarises the key findings in relation to the original thesis aims and outlines recommendations for future research.

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Chapter Two – Rural impacts of New Zealand's 14 November 2016 'Kaikōura' earthquake

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Preface

This chapter investigates how the 2016 'Kaikōura' earthquake impacted rural communities and sectors on the northern South Island of New Zealand, by focusing on the 12 months following the event to better understand what can happen in a high-income nation following a complex earthquake with multiple co-seismic hazards.

2.1. Abstract

The 14 November 2016 M_w 7.8 'Kaikōura' earthquake and associated co-seismic hazards strongly affected the north of New Zealand's South Island, an area of high-intensity livestock and crop farming, which is supported by predominantly rural service towns. The most severely affected areas were the largely rural Hurunui, Kaikōura, and Marlborough Districts, where extreme ground shaking resulted in widespread damage to critical infrastructure, services outages, and structural damage to agricultural equipment. Nearly two minutes of ground shaking resulted in the generation of over 10,000 co-seismic landslides in the mountainous terrain. These landslides, and to a certain extent surface fault ruptures, dammed rivers, destroyed bridges, and disrupted large portions of the land transportation network, effectively isolating some farms and farming communities. This report uses the Kaikōura earthquake as a case study to synthesise the disaster impacts and response and recovery challenges caused by a large earthquake with complex co-seismic hazards to rural communities and sectors in a high-income nation. The initial 12 months following the disaster are investigated through interviews, geospatial assessments, and analysis of peer-reviewed articles, organisational reports, and other grey literature associated with the event. Results show that earthquake impacts compounded a highly stressed rural region that had experienced a three year drought immediately prior. This multi-hazard context was found to be a key driver of disaster risk in this case study, with many rural actors feeling more strongly burdened by the long-term drought conditions compared to the relatively acute, comparatively short effects of the earthquake. The earthquake impacts prevented many from being able to address the on-going drought impacts to their agricultural sectors. The pre-existing organisational resilience of individuals through to whole sectors was found to be another key driver of disaster risk, but highlights a need for a holistically coordinated organisational sector. A lack of integrative coordination within the rural region, within the responding actors (including rural organisations, industry groups, and government agencies), and between the two may have hindered response and recovery operations. While this work focuses on a New Zealand case study, the lessons presented here have wide implications for reducing rural impacts to natural hazards in other similar contexts, and enabling more informed and evidence-based decision-making during future rural disaster planning and response efforts.

2.2. Introduction

Understanding and assessing disaster impacts from natural hazards is an essential step of disaster risk reduction (DRR) (UNDRR, 2015). To help robustly inform such assessments, it is important to analyse the impacts and effectiveness of disaster resilience strategies from previous disasters. In the case of earthquake disaster resilience, there is a wealth of studies analysing impacts and resilience lessons to the built environment and urban communities affected by earthquake hazards (Godschalk, 2003; Pelling, 2003; Sheridan and Dolnev, 2003; Vale and Campanella, 2004; Borden et al., 2007; Allan et al., 2013). But there has been comparatively less focus on rural communities and associated industries in the global disaster literature (Bankoff et al., 2004; Brennan and Flint, 2007; Cutter et al., 2016). In some cases, this disparity has also been highlighted through the limited media coverage received in rural areas compared to nearby urban areas affected by the same event (Brennan and Flint, 2007).

It is relatively well established that rural communities and industries have different and sometimes distinctly unique disaster resilience attributes when compared with urban communities and industries (Boon, 2004; Leichenko, 2011; Cutter et al., 2012; McManus et al,, 2012; Romero-Lankao et al., 2012; Skerratt, 2013). For example, access to services in rural areas is often more limited compared to urban areas (Ravallion et al., 2007). Other studies have shown that rural communities may not readily have access to the additional resources and capacities needed to respond to and recovery from a disaster (Kapucu et al., 2013; Waugh, 2013; Cox and Hamlen, 2015). This lack of financial and human resources has been shown to reduce rural disaster resilience (Janssen, 2006). It is also established that rural communities and industries can be highly vulnerable to the hazards caused by large earthquakes, in particular those situated in mountainous terrain (Shaw and Sinha, 2003; McCrink et al., 2011; Whitman et al., 2013; Chapagain and Raizada, 2017; Cui et al., 2018), although many of these studies have focused on earthquake disasters in low-income nations (Hausler, 2004; Symmes, 2016; Chapagain and Raizada, 2017; Cui et al., 2018; UN FAO, 2018). General themes are that remoteness and rugged terrain were shown to cause logistical challenges for organisations, aid, and skilled repair workers responding from outside the region (Drabek et al., 1981; Wang et al., 2011; Murphy et al., 2014) (see also Table 2.1). The economic impact of disasters in low-income nations can also be particularly severe, compounding other social stressors (Lock et al., 2012) and resulting in 'poverty traps' (Carter et al., 2008). However, there are comparatively few studies on earthquake impacts and issues experienced by rural communities and sectors in

high-income nations (Sabates-Wheeler et al., 2008; UNDRR, 2009; Cutter et al., 2016). While this focus on low-income nations is very appropriate, given the higher levels of exposure and vulnerability (Carter et al., 2008; Krishna et al., 2018; World Bank, 2013), the comparative lack of earthquake impact and resilience research studies for rural communities and industries in high-income countries is a notable gap.

New Zealand is an opportune country to examine rural disaster risk reduction and resilience. It is a high-income nation whose national economy is underpinned by a high reliance on the primary industries, compared to other high-income nations (Kamber et al., 2013). New Zealand is also highly exposed to natural hazards, as an island nation situated on the boundary of two tectonic plates and at a latitude which exposes the country to both sub-Antarctic storms and ex-tropical cyclones (MCDEM, 2007). New Zealand has a very high seismic hazard by global standards (Stirling et al., 2012; Horspool et al., 2017), and has experienced a number of damaging earthquakes over the past 150 years, with two recent highly impactful earthquake sequences affecting the country in 2010 and 2011 with the Canterbury Earthquake Sequence and in 2016 with the Kaikōura earthquake and aftershock sequence (Potter et al., 2015; Stevenson et al., 2017).

This study assesses the disaster impacts, response, and early recovery challenges and opportunities experienced by rural communities and industries following the 2016 Kaikōura earthquake in the northern South Island of New Zealand. It includes an important secondary objective of analysing this disaster in a multi-hazard impact context. The earthquake caused a suite of co-seismic hazards including ground-shaking, fault rupture, liquefaction, widespread landslides, and landslide dams with associated flooding, which all caused different direct and indirect impacts in space and time. The region had also been affected by severe drought in preceding years to the earthquake, and (MPI, 2017a). The study contributes to understanding rural disaster resilience in a multi-hazard context through a New Zealand case study lens. This report begins with a review of recent global earthquakes which have severely impacted rural communities and industries, then contextualises rural New Zealand by sharing summarising attributes relevant to disaster vulnerability and resilience, and the associated disaster risk management arrangements. Then the rural-specific impacts to northern South Island rural communities and industries from the Kaikōura earthquake and associated co-seismic hazards are explored quantitatively through a geospatial exposure analysis, and qualitatively through

thirteen in-depth interviews with local and external actors directly involved and/or affected by the response and recovery activities.

2.3. Rural earthquake disasters

2.3.1. Conceptual framework and definitions

The Sendai Framework for Disaster Risk Reduction 2015 – 2030 is the predominant international framework for disaster risk reduction efforts (UNDRR, 2015). The first of its four priority areas for action guides the motivation for this study: to increase the "understanding of disaster risk in all its dimensions" as a means to inform the wider management of policies and practices aimed at reducing disaster risk (UNDRR, 2015). Disaster risk assessments are used to understand disaster risk; these are defined as a "qualitative or quantitative approach to determine the nature and extent of disaster risk" (UNDRR, 2016) and can include "the identification of hazards, (…) the analysis of exposure and vulnerability, including the physical, social, health, environmental and economic dimensions, and the evaluation of the effectiveness of prevailing and alternative coping capacities" (UNDRR, 2016). Disaster risk assessments therefore rely on understanding the likely impacts caused by natural hazards.

Within this report, we adopt the terminology as set out by the United Nations Office for Disaster Risk Reduction (UNDRR) (UNDRR, 2016). However, the UNDRR does not provide a definition for what constitutes a 'rural' region. While there is no standard and internationally recognised definition for 'rural' regions, these are typically viewed as non-urban areas with low population densities (UN, 2019). It has been recognised internationally that urban / rural classifications are difficult to implement when solely using population density as a metric (Hathout, 2002), with characteristic-based urban / rural classification schemes are being developed in multiple countries as a way to provide better distinction between the variety of communities that exist outside of urban centres (Teljeur and Kelly, 2008). Therefore this work adopts a definition of 'rural' categorised by the New Zealand government as "highly rural / remote areas" and "rural areas with low urban influence" which are determined by comparing residential and workplace addresses of employed populations in that area (Statistics New Zealand, 2004a; Statistics New Zealand, 2004b).

This distinction between rural and urban settings is important to define when considering disaster risk and resilience, as the context in which a disaster occurs is a key indicator as to the type and severity of impacts that may develop (Janssen, 2006). For example, in the rural context, some resources and capacities can be considered higher than in urban areas, due in part to an increased general level of self-sufficiency which includes: typically greater food availability on hand, likely access to natural water sources, and more readily available earth moving and farm machinery (Bruneau et al., 2003; Ellemor, 2005; Almond et al., 2010; Waugh, 2013; Espiner and Becken, 2014; Murphy et al., 2014; Cox and Hamlen, 2015; Aoki, 2018). These elevated capacities can lessen the level of impact a disaster might have in rural regions (Janssen, 2006). Conversely, the vulnerability of rural regions can in some ways be higher than that of urban areas, due to a physical separation from services (such as healthcare clinics and emergency services) and markets, a reliance on long distributed infrastructure networks, and the need to adhere to specific agribusiness timeframes and seasonal cycles (Ye and Abe, 2012; Espiner and Becken, 2014; Gardner, 2015). Additionally, the ongoing degradation of ecosystems reduces the capacity of rural sectors and regions to cope with the impacts of natural hazards and provide for basic needs (such as water, food, and shelter) before, during, and after a disaster (Joerin et al., 2012; Renaud et al. 2013; Tanner et al., 2015; Rakotobe et al., 2016).

2.3.2. Past global rural earthquakes and impacts

A number of large earthquakes have affected primarily rural regions around the world over the past two decades, causing multi-faceted and complex impacts (Chapagain and Raizada, 2017). A summary of key learnings from these events are listed in Table 2.1, covering a range of compounding organisational, societal, environmental, financial, and critical infrastructure service issues (see references within Table 2.1). Notably, common aspects across the rural earthquakes was that damaged infrastructure was a key problem, and the remoteness of rural areas was an additional barrier to effective disaster response and continued recovery. For rural earthquake disasters in India, China, Mexico, Haiti, and Nepal challenges also included assessing the extent of structural damage and immediate impacts caused by their respective earthquakes, acquiring resources to support the response and recovery (such as heavy machinery and skilled labourers), and coordinating incoming aid donations and response and

recovery actors (Shaw and Sinha, 2003; Kolbe et al., 2010; McCrink et al., 2011; Dey, 2015; Cui et al., 2018). For the 2010 Darfield earthquake disaster in New Zealand, disruptions to critical infrastructure (especially electrical services and water supply) and equipment were the key issues (Whitman et al., 2013). The 2010 Baja California (Mexico) earthquake impacts similarly included damaged agricultural infrastructure and lands (Wilson et al., 2011). Challenges faced by one country, such as weak DRR governance in Haiti, do not necessarily apply to other countries, such as New Zealand, which is recognized as having strong DRR governance (IFRC, 2014).

This underlies an important consideration for rural disaster resilience to earthquakes: while rural disasters do have common traits globally, the type and level of impacts experienced are still highly dependent on the local and national contexts. High-income countries generally have greater available resources (i.e. capacities) for addressing response and recovery in their farming communities (Lavell and Maskrey, 2014; Linnerooth-Bayer and Hochrainer-Stigler, 2015; Rechel et al., 2016; Zorn, 2018). Conversely, high-income farming communities may also, for example, rely on highly sophisticated modern farming technology, while low-income or subsistence farming communities may not require similar specialised machinery repair technicians following a disaster (Shaw and Sinha, 2003; Pomeroy et al., 2006; UN FAO, 2008; Nepal Government, 2015). These different contexts and disaster response needs can directly affect levels of impact experienced following an earthquake.

Table 2.1 Recent major earthquakes primarily affecting rural regions, and major associated response and recovery challenges.

Date	Name	M_w	Country	United Nations country classification	Impacts	Major challenges reported	References
26 January 2001	Gujarat earthquake (sometimes referred to as the Bhuj earthquake)	7.7	India	Lower-middle-income	20,000 fatalities $117 million USD losses to agricultural sector; Low losses as little mechanisation.	Inaccurate assessment of damage extent due to poor communication; Lack of equipment to clear debris; Lack of experienced and skilled personnel; Poor coordination and involvement of stakeholders; Production losses mainly associated with delays in harvesting, labour shortages, damage to irrigation, damage to grain storage facilities; Human welfare needs addressed, but agricultural and livestock management relief minimal.	Shaw and Sinha, 2003; Hausler, 2004; Phalkey et al., 2011; United Nations, 2015; World Bank and ADB, 2015; Chapagain and Raizada, 2017
12 May 2008	Wenchuan earthquake (sometimes referred to as the Great Sichuan earthquake)	7.9	China	Upper-middle-income	$6 billion USD damages estimated for agricultural sector; 30 million rural community residents affected with many of their assets lost; Thousands of hectares of farmland were destroyed; Millions of farm animals died; Thousands of pieces of agricultural machinery was damaged; Rice fields dried up and irrigation systems interrupted.	Many rural residents have lost their means to produce food and create income; 3-5 years estimated to rebuild local agriculture sector; Deaths and injuries to farming families created a lack of labourers; Immediate challenge in providing fertilizers, pesticides, farm tools, and livestock; Medium and long-term challenge to rehabilitate water reservoirs and dams.	UN FAO, 2008; Cui et al., 2018
4 April 2010	Baja California earthquake (sometimes referred to as the Sierra El Mayor – Cucapah earthquake)	7.2	Mexico	Upper-middle-income	$500 million USD in damage in Mexico, plus $50 million USD in damage in the USA; 2 fatalities and hundreds of injuries; 140 km surface rupture. Liquefaction and ground shaking damaged buildings, bridges, earthen dams, roadways, and especially agricultural lands and infrastructure; Contaminated groundwater; Changes to ground level and water table level affected irrigation canals and drains.	Damage to irrigation systems and changes to groundwater table rendered some agricultural land unusable; Agricultural infrastructure was damaged; Lengthy recovery time for local agricultural industry; Poor understanding of localised impacts to primary industries (given large spatial footprint).	Chapagain and Raizada, 2017; McCrink et al., 2011; Wilson et al., 2011

12 January 2010	Haiti earthquake	7.0	Haiti	Low-income	25% of national population impacted. 600,000 person exodus from urban to rural regions; Severe damage to infrastructure across the country; Rural subsistence economy suffered substantial post-harvest losses; Food insecurity.	Lack of equipment to clear debris; Lack of experienced and skilled personnel; Weak government and complex protocols; Transportation and distribution of aid problematic; Poorly coordinated and regulated donations; Increased burdens on already impoverished rural regions.	Haiti Government, 2010; Kolbe et al., 2010; Da Costa et al., 2014; Risler et al., 2015; Chapagain and Raizada, 2017
4 September 2010	Darfield earthquake (part of the Canterbury Earthquake Sequence)	7.1	New Zealand	High-income	Surface rupture and liquefaction; Land level changes; Air and water quality levels affected; Critical services outages and damage to infrastructure; Stress impact on livestock productivity.	Increased risk of flooding; Infrastructure and ecosystem damage; Decreased farm productivity; Business continuity and cash-flow issues; Elevated levels of stress; Large aftershock months later in nearby urban centre diverted attention from rural recovery.	Almond et al., 2010; Glassey and Wilson, 2011; Van Dissen et al., 2011; Whitman et al., 2013; Potter et al., 2015; Quigley et al., 2016
25 April 2015	Nepal earthquake (sometimes referred to as the Gorkha earthquake)	7.8	Nepal	Low-income	Affected ~1 million smallholder farms; $284 million USD in damage and losses; Damage and losses to crop lands, physical infrastructure, greenhouses, livestock shelters, agricultural tools, equipment, and machinery; Stored seeds were buried under rubble.	Number of farms affected. Remote hill setting hindered emergency relief; Problems in decision making / lack of political consensus; Poor coordination of response and recovery actors; Lack of mechanism for tracking flow of aid; Long term agricultural recovery efforts focused on regions nearer to cities and only reached thousands of farmers.	Dey, 2015; Nepal Government, 2015; Chapagain, 2015; Symmes, 2016; Tayler, 2016; Chapagain and Raizada, 2017

2.3.3. New Zealand rural DRR context

The New Zealand approach to emergency management is guided by the Civil Defence and Emergency Management (CDEM) Act 2002, which outlines a national framework for disaster risk reduction, readiness, response, and recovery (New Zealand Legislation, 2019). The CDEM Act 2002 mandates that the government response to earthquake disasters in both rural and urban settings be led by the National Emergency Management Agency (NEMA), known as the Ministry for Civil Defence and Emergency Management (MCDEM) at the time of the Kaikōura earthquake. The National CDEM Plan 2015 sets out the governance structure for responding government agencies (MCDEM, 2015), with Figure 2.1 showing the theoretical

arrangements between MCDEM, the CDEM Groups, and other government agencies (such as the Ministry for Primary Industries).

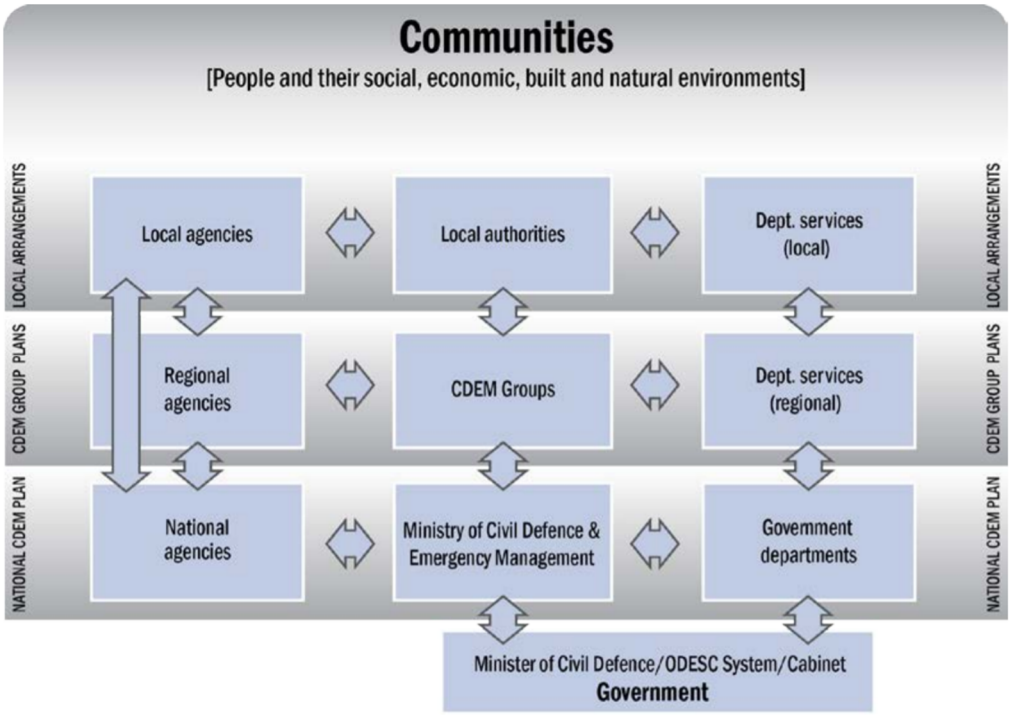

Figure 2.1 Inter-relationships between core CDEM agencies and other government departments and agencies who support communities to manage emergencies (MCDEM, 2015).

However, multiple other government agencies, regional and local councils, private businesses, and other non-government organisations are responsible for aspects of disaster risk reduction practices and processes, which are mandated through multiple other legislative Acts, including the Resource Management Act 1991, the Local Government Act 2002, the Building Act 2004, and the Health and Safety at Work Act 2015 (NEMA, 2020a). In the rural context, the primary industries in New Zealand generally have strong sector based organisations which provide resource, support, and lobbying for members (such as DairyNZ and Beef and Lamb), large agribusinesses (such as Fonterra), rural-based organisations (such as Federated Farmers and the Rural Support Trusts), and the Ministry for Primary Industries (MPI).

The primary sector (which consists of agriculture and associated services) accounts for a considerable amount of the New Zealand economy, generating 7.5% of national gross domestic product (GDP) in 2015 (Statistics New Zealand, 2016), and contributing to over 50% of New Zealand's total export earnings for that year (New Zealand Treasury, 2016). Flow-on effects from the primary sector (such as processing, manufacturing and rural transport

businesses) account for an additional 17% of GDP (MCDEM, 2007). Tourism is another major contributor to the New Zealand economy, accounting for 5.8% of annual GDP (Statistics New Zealand, 2020b), and relies on the natural environment, picturesque scenery, and a range of outdoor activities that primarily occur in rural areas. Rural regions are therefore a vital component of the national economy and to New Zealand's international exports (New Zealand Treasury, 2016).

According to a 2013 census, 6.8% of the New Zealand population lives in highly remote or rural areas with low urban influence (Cochrane and Maré, 2017; Statistics New Zealand, 2020c). Many of these rural regions are experiencing stagnation (Cameron, 2017) or decline (Jackson and Brabyn, 2017) in their population numbers. Additionally, rural areas in New Zealand are seeing a drop in 22-44 year olds, coupled with an increase in those 65 years and older (Cochrane and Maré, 2017).

Over the past 15 years a range of natural hazards have affected rural New Zealand (Spector et al., 2019), with multiple post-disaster reviews listing comparable lessons and experienced impacts following, for example, tsunami (MCDEM, 2016), fires (MCDEM, 2019a), earthquakes (MCDEM, 2019b), landslides (GNS, 2016), and severe weather and flood (Otago Regional Council, 2015) events, as well as planned emergency management exercises (MCDEM, 2017a). An after-action report by Animal Evac New Zealand (a non-governmental organisation) after the Nelson Fires of February 2019 note that the lessons identified in their report (such as poor pre-event planning, lack of coordination, and lack of vertical communication between agencies) were already identified in previous rural disaster after-action reports (Glassey and Anderson, 2019). More generally, the impacts experienced by many rural disasters include elements of critical service outages and damage to infrastructure (Whitman et al., 2013); livestock welfare issues (Almond et al., 2010; MPI, 2012; Squance et al., 2018); a need for enhanced cross-sectoral approaches to response and recovery (Beaven, 2017); better warning systems (Glavovic et al., 2010); and, inadequate communication between rural communities and the government response (Paton et al., 1998; Smith et al., 2011). Key drivers of disaster risk in rural New Zealand include: the changing make-up of rural society (such as evolving demographics) (Smith et al., 2011; Cameron, 2017); evolving agribusiness practices (such as the use of modern farming technology, a longer distributed service network, and crop yield intensification) (MacLeod and Moller, 2006; Smith et al., 2011); levels of critical infrastructure connectivity (Davies et al., 2017); a resource-dependent livelihood coupled with

a vulnerable and evolving ecosystem (Pomeroy and Newell, 2011; Harrington et al., 2014); legislation which does not always suitably address rural needs (Seville et al., 2008; Rotimi et al., 2009; Paton et al., 2014); high levels of transient tourism to remote areas (such as the Franz-Josef Glacier and Milford Sound) (Orchiston, 2012); and community resilience and involvement in emergency response and recovery (Millar et al., 2000; Paton et al., 2000; Becker et al., 2001; Paton et al., 2001; Paton and Johnston, 2001; Ronan et al., 2001; Thornley et al., 2015; Kwok et al., 2016).

Multiple strategies are used to increase rural resilience to disaster impacts in New Zealand. A strong national level response and recovery legislation (the CDEM Act 2002, and subsequent amendments) provides strong national governance structures and direction before, during, and after natural hazards, reducing potential impacts (IFRC, 2014). Unfortunately, this national level legislation has been found to have patchy and relatively weak implementation at local levels (IFRC, 2014; Basher, 2016; Saunders et al., 2020), and does not distinguish between the specific needs of both urban and rural areas for disaster planning and disaster response (New Zealand Legislation, 2019). Additionally, a legislative and practical need for increased cross-sectoral collaboration and coordination to address structural issues in rural disaster risk reduction and response persists (Rotimi et al., 2009; Basher, 2016, UNDRR, 2020).

Other factors in New Zealand also help increase rural resilience and helps lessen rural disaster impacts. One of which is a robust building code resulting in high construction standards for infrastructure and strong regulations for buildings, which are regularly enforced (Buckett, 2014; New Zealand Legislation, 2020). New Zealand is also extremely well insured compared to other countries (Insurance Council of New Zealand, 2020), and has one of the highest take-up rates of residential insurance against natural hazards in the world (Nguyen and Noy, 2020), at over 90% (Fleming et al., 2018). This is enabled, in part, through the Earthquake Commission (EQC), a government supported insurance scheme that covers residential properties and land (including agricultural land) against the impacts of many natural hazards, including earthquakes (see www.eqc,govt.nz), and therefore absorbs a large portion of economic costs and losses following a disaster. This high level of insurance coverage helps lesson the economic impacts of disasters (Linnerooth-Bayer and Mechler, 2008). While poverty exists in New Zealand (Boston, 2013), the country exhibits below average levels of impoverishment (OECD, 2019), with 11% of the population living in poverty relative to the national median (OECD, 2020a) as compared with 18% in the USA (OECD, 2020b) and 16% in Japan (OECD, 2020c). New

Zealand also exhibits low levels of perceived corruption, has a modern form of government, education, and infrastructure, and boasts strong social welfare support and health care systems (OECD, 2019). These factors all directly influence the level of impact that can be expected following a disaster (Dowrick, 2003). In addition, New Zealand hosts a strong cadre of highly trained emergency management professionals (NEMA, 2020b). Finally, these practitioners and policy experts are supported by a vibrant natural hazard risk and disaster resilience research sector in New Zealand (such as Resilience to Nature's Challenges, see https://resiliencechallenge.nz/). However, gaps in scientific research focused on rural resilience and rural impacts within New Zealand exist. A recent review by Spector et al. (2019) of the rural resilience studies carried out in New Zealand found that research was: limited in spatial extent; tended towards quantitative investigations; poorly understood the perspective and role of Māori (the country's indigenous people) despite their considerable rural land management responsibilities; showed limited evidence of collaboration with stakeholders; and did not adequately encapsulate the diverse range of risks, hazards, and impacts potentially experienced by different populations across the nation.

2.4. Methodology

This study uses a mixed-methods approach to qualitatively explore disaster impacts to rural north South Island following the 2016 Kaikōura earthquake. Firstly a geospatial exposure analysis is undertaken to assess the number of rural residences and farms exposed to the ground shaking associated with the earthquake across the South Island. The shaking experienced on the North Island was not considered as part of this rural South Island study.

Then a combination of local and external response and recovery actors to the area were interviewed, to gain insight into their professional experiences and personal learnings from the event. Interviews focused on the Kaikōura and Hurunui Districts (jointly referred to as North Canterbury), as these regions were considered the most strongly affected by the earthquake, having "suffered the bulk of the damage" (NEMA, 2020c). Given the complex and multi-faceted nature of the social issues explored as part of this study, semi-structured interviews were used (Mason, 2002; Patton, 2002). Participants (n = 13) were invited to contribute to this study based on their professional roles and experiences (Table 2.2). They were identified initially by role and author's networks, then subsequently through the process of 'snowballing'

as interviews proceeded (Patton, 2002). The interview process ended when adequate representation was considered to have occurred, and information saturation reached, as identified by the authors. Ideally this research would have gathered qualitative data from a diverse range of rural participants. However, given the enduring impacts of the earthquake at the time of interviews (approximately one to two years after the event) it would have been unethical and insensitive to increase the stress of rural populations by subjecting them to additional research pressures. This has been identified as a breach of fundamental ethical principles, most recently following the 2010 – 2011 Canterbury Earthquake Sequence (Beaven et al., 2016). Largely for this reason, perspectives from a wider range of rural society (including groups such as the elderly, disabled, and migrant farm workers) were purposefully omitted from this study. Most interview participants were professionally trained emergency managers active in the response to the Kaikōura earthquake, or had an official response role in local and regional government. Efforts were made, however, to interview individuals that were well networked in rural communities to provide a degree of insight into the experiences of vulnerable communities.

Ethical review and approval was obtained from the University of Canterbury's Human Ethics Committee (reference number: HEC 2017/34/LR-PS). Interviews were one-on-one, conducted by the lead author, recorded, transcribed, and manually coded using spreadsheet software. The methodology for coding followed an inductive framework analysis process, as outlined by Thomas (2006). Relevant text segments from the transcripts were identified, labelled, reduced to major themes, and used to distil the most important categories.

Table 2.2 Distribution of study participants across level and profession

		Occupation	
		Professional emergency manager	Member of rural organisation
Level at which operates	National	2	1
	Regional	4	1
	Local	4	1

This work integrates results from the interviews with learnings from applicable peer-reviewed articles and publically available organisational reports. Participant observation at

local workshops, regional conferences, and national conferences by the author contributed to general understanding, and provided additional context for interpretation of the interviews.

2.5. Results

2.5.1. The 14 November 2016 'Kaikōura' earthquake

On 14 November 2016 at 12:02am, 25 fault lines in the northern Canterbury region of the South Island ruptured to produce a moment magnitude (Mw) 7.8 earthquake (GeoNet, 2016; Hamling et al., 2017). While the earthquake was named the 'Kaikōura' earthquake given the impacts to the nearby Kaikōura township (GeoNet, 2017), it strongly affected the northern South Island, especially the Hurunui, Kaikōura, and Marlborough Districts, and the lower North Island, including Wellington (New Zealand's capital) (GeoNet, 2020a). The analysis and maps presented in Figure 2.2, Tables 2.3, 2.4, and 2.5, respectively, shows the large spatial extent of the ground shaking, which resulted in a wide variety of rural livelihoods affected by the Kaikōura earthquake.

The earthquake was reported as one of the most complex seismic events ever recorded, in part because the rupturing jumped sequentially from fault to fault (Hamling et al., 2017). Ground shaking in places lasted nearly 2 minutes in total, and resulted in up to 12 metres of combined horizontal and vertical ground displacement in some areas (GeoNet, 2020a). The highest levels of perceived ground shaking occurred in North Canterbury (Hurunui and Kaikōura Districts) and Marlborough (Figure 2.2c). Over 20,000 recorded aftershocks occurred in the 12 months following the initial rupture (GeoNet, 2020b). This earthquake sequence caused tens of thousands of landslides in a 10,000 square kilometre area, with several blocking rivers and causing approximately 150 landslide dams across the South Island (MCDEM, 2017; GeoNet, 2018). Additionally, a tsunami was generated with waves at the coast peaking at nearly 7 metres in places (Power et al., 2017), likely generated by offshore coastal uplift (Hamling et al., 2017). Fortunately, damage from this tsunami was minor as the tsunami arrived close to low tide, much of the coastline was uplifted during the earthquake, and the beaches along the Kaikōura coast are steep (GeoNet, 2020a).

Landslides, and to a certain extent surface fault ruptures, disrupted critical infrastructure (also known as 'lifelines' in New Zealand) such as roads (Davies et al. 2017), power (Liu et al., 2017), water (Hughes et al., 2017), and telecommunications (Giovinazzi et al., 2017). While power and telecommunication outages were mostly resolved within 48 hours of the initial earthquake (Lui et al., 2017), the land transportation network was highly disrupted (Davies et al., 2017). Some remote farms and farming communities in the Hurunui and Kaikōura Districts were completely inaccessible by land (Davies et al., 2017). Access to and from some rural areas, especially those nearest the epicentre where the hilly terrain resulted in widespread landslides, was cut-off, and the resulting isolation disrupted the movement of people and goods (Davies et al., 2017). Direct damage, such as physical damage to farming machines and infrastructure, was therefore not able to be rapidly repaired, effectively cutting rural value chains and access to markets. It was on 20 November 2016, four full days after the initial earthquake, that government responders were "now able to investigate rural and isolated communities" (NZDF, 2016). The immediate response focus and aid was geared towards the large number of concentrated residents and stranded tourists in the township of Kaikōura. As one interview participant put it:

> What was happening was – and it was perfectly reasonable – but the focus [of the response] was on the townships. And in some cases, nobody had ever checked the outlying farms to see that they were okay or nobody had information to know that they were okay.

Early attention from the official government response was mostly directed towards the more populous areas, meaning that the some remote and rural communities were isolated for longer periods of time compared to townships such as Kaikōura. Many farmers and rural residents were forced to deal with the immediate impacts of the earthquake on their own.

While Christchurch was the nearest major urban region to the epicentre, the south-west to north-east rupturing of the faults directed seismic energy to the northeast, resulting in Wellington experiencing much higher ground shaking intensities and associated impacts despite being over 200 kilometres away from the epicentre of the earthquake (Henry et al., 2017). Sadly, two fatalities were attributed to this earthquake (one in the Kaikōura District and one in the Hurunui District), along with 624 injuries (Horspool et al., 2017). Within 6 months of the initial earthquake, approximately 38,000 residential insurance claims were made to the EQC addressing residential and land property damage (MCDEM, 2017; EQC, 2019).

2.5.2. Rural exposure to earthquake shaking

Over 22,000 farms and rural properties were exposed to ground-shaking from the Kaikōura earthquake, with intensity levels on the NZ Modified Mercalli Intensity (MMI) scale ranging from Largely Observed (MMI 4) to Very Destructive (MMI 10) (GNS, 2020). Over 10,000 farm businesses were exposed to 'strong' (MMI 5) or higher levels of ground shaking (Table 2.3). A graphical overview of the relationship between ground-shaking and other aspects of rural society in the north part of the South Island is presented in Figure 2.2. This figure provides information on the jurisdictional boundaries to the region and location of key transportation networks (Figure 2.2a), population density and disruption to access along the road network as of 16 November 2016 (Figure 2.2b), the spatial distribution of ground shaking and location of the ruptured faults (Figure 2.2c), the density of regional farms (Figure 2.2d), the spatial distribution of different farm types (Figure 2.2e), and the spatial layout of land cover usage for the region (Figure 2.2f). The extent to which individual rural property types have been exposed to different levels of ground shaking can be seen in Table 2.3. Results from this table show that nearly half (48.27%) of the rural properties affected by the earthquake were subject to 'slightly damaging' (MMI 6) levels of ground shaking. Additional maps detailing the exposure to ground shaking for individual property types (and sectors) are presented in the Appendix (Section 2.10). The cumulative spatial extent of farm types exposed to different levels of ground shaking is presented in Table 2.4. Results show mixed sheep and beef farms account for the largest percentage (43.55%) of land exposed to ground shaking from this earthquake, while lifestyle blocks only account for 2.07% of the total area affected, despite being the farm type with most units exposed (53.2%) (Table 2.3). The number of livestock exposed to different levels of ground shaking are presented in Table 2.5. Results show, for example, that around 3 times as many sheep were exposed to ground shaking when compared to cattle.

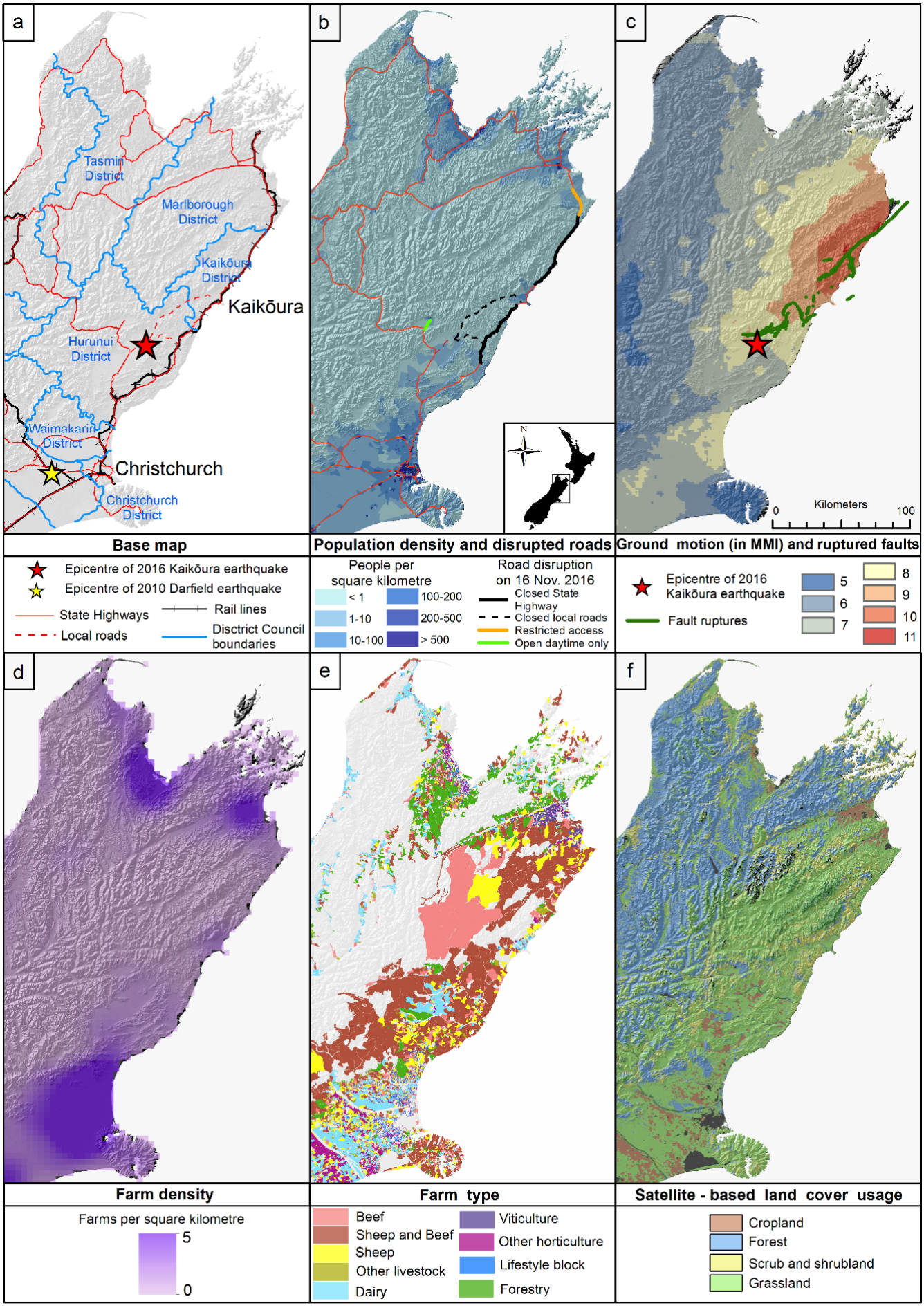
a
Tasman District
Marlborough District
Kaikōura District
Kaikōura
Hurunui District
Waimakariri District
Christchurch
Christchurch District
b
N
c
0
Kilometers
100
Base map
Epicentre of 2016 Kaikōura earthquake
Epicentre of 2010 Darfield earthquake
State Highways
Local roads
Rail lines
Disctrict Council boundaries
Population density and disrupted roads
People per square kilometre
< 1
1-10
10-100
100-200
200-500
> 500
Road disruption on 16 Nov. 2016
Closed State Highway
Closed local roads
Restricted access
Open daytime only
Ground motion (in MMI) and ruptured faults
Epicentre of 2016 Kaikōura earthquake
Fault ruptures
5
6
7
8
9
10
11
d
e
f
Farm density
Farms per square kilometre
5
0
Farm type
Beef
Sheep and Beef
Sheep
Other livestock
Dairy
Viticulture
Other horticulture
Lifestyle block
Forestry
Satellite - based land cover usage
Cropland
Forest
Scrub and shrubland
Grassland

Figure 2.2 (a) Territorial map of northern South Island, New Zealand, with major road and rail transportation networks; (b) Population density (2013 New Zealand Census) and transportation outage of road network on 16 November 2016 (Davies et al., 2017); (c) Ruptured faults and spatial distribution of ground shaking using Modified Mercalli Intensity (MMI) scale (model data from Bradley et al., 2017); (d) Number of individual farms in region (AgriBase, 2018); (e) Farm types (AgriBase, 2018); (f) Land use classes (Land Cover Database, Version 4.1a, 2017).

Table 2.3 Number of farms exposed to different levels of ground shaking (MMI) from the 2016 Kaikōura earthquake. Data from the 2018 AgriBase spatial database.

	MMI experienced (mean value)								
	4 Largely observed	**5** Strong	**6** Slightly damaging	**7** Damaging	**8** Heavily damaging	**9** Destructive	**10** Very destructive	Total	%
Beef farms	155	397	946	514	43	23	1	2,079	9.13
Dairy farms	206	363	657	185	20	19	0	1,450	6.37
Sheep farms	48	204	778	286	40	32	2	1,390	6.10
Mixed sheep and beef farms	104	275	648	224	77	53	6	1,367	6.00
Deer farms	22	82	175	88	7	7	0	381	1.67
Pig farms	2	7	29	19	0	2	0	59	0.26
Other livestock farms	5	30	129	54	0	0	0	218	0.96
Lifestyle blocks*	537	1,787	5,880	3,632	176	99	3	12,114	53.20
Viticulture farms	2	1	151	385	58	6	1	604	2.65
Horticultural farms	112	377	1,598	908	77	13	4	3,089	13.57
Total	1,193	3,523	10,991	6,295	498	254	17	**22,771**	**100**
%	5.24	15.47	48.27	27.65	2.19	1.16	0.07	**100**	

*Lifestyle blocks are often referred to as "hobby farms" outside New Zealand, and are typically used for small-scale farming or residential purposes.

Table 2.4 Cumulative spatial extent (in Ha) of farm types exposed to different levels of ground shaking (MMI) from the 2016 Kaikōura earthquake. Data from the 2018 AgriBase spatial database.

		MMI experienced (mean value)								
		4	**5**	**6**	**7**	**8**	**9**	**10**	Total	%
Total area exposed (in hectares)	**Beef farms**	16,293.91	46,273.23	302,415.42	25,360.39	8,777.29	4,731.45	1,046.30	404,897.99	13.00
	Dairy farms	52,843.18	118,435.61	198,925.52	57,741.61	5,743.43	4,743.53	0.00	438,432.88	14.08
	Sheep farms	20,462.65	59,710.10	175,710.33	32,781.33	17,419.82	14,576.79	946.43	321,607.45	10.33
	Mixed sheep and beef farms	218,945.65	386,666.28	341,166.22	235,313.94	95,121.64	68,040.35	10,963.97	1,356,218.05	43.55
	Deer farms	6,972.77	25,289.03	15,793.17	3,634.41	2,126.45	3,922.76	0.00	57,738.59	1.85
	Pig farms	68.80	376.63	2,158.59	895.16	0.00	47.99	0.00	3,547.17	0.11
	Poultry farms	4.02	93.82	1,063.73	295.58	0.00	0.00	0.00	1,457.15	0.05
	Other livestock farms	93.19	622.24	1,232.65	301.87	0.00	0.00	0.00	2,249.95	0.07
	Lifestyle blocks	3,596.23	12,465.44	28,546.88	18,532.29	779.72	584.46	14.76	64,519.78	2.07
	Viticulture farms	178.18	3.22	7,938.87	14,897.27	4,581.75	82.58	41.46	27,723.33	0.89
	Forestry farms	55,330.03	67,502.37	157,350.57	30,063.15	357.64	306.25	1,346.86	312,256.87	10.03
	Other horticultural farms	610.90	12,014.46	83,710.69	26,669.46	701.00	72.00	0.00	123,778.51	3.97
	Total	375,399.51	729,452.43	1,316,012.64	446,486.46	135,608.74	97,108.16	14,359.78	**3,114,427.72**	**100**
	%	12.05	23.42	42.26	14.34	4.35	3.12	0.46	**100**	

Table 2.5 Number of livestock exposed to different levels of ground shaking (MMI) from the 2016 Kaikōura earthquake. Data from the 2018 AgriBase spatial database.

	MMI experienced (mean value)								
	4	**5**	**6**	**7**	**8**	**9**	**10**	Total	%
Cattle	131,422	334,194	777,314	251,187	46,264	27,760	1,702	1,569,843	15.19
Sheep	285,485	898,084	2,245,154	691,107	334,879	164,217	17,725	4,636,651	44.88
Deer	26,192	101,916	79,467	24,745	11,327	3,688	0	247,335	2.39
Pig	297	11,238	57,003	33,712	3,187	806	6	106,249	1.03
Poultry	80	304,493	2,617,980	763,658	0	0	0	3,686,211	35.68
Other	5,530	12,863	42,924	21,457	2,037	715	85	85,611	0.83
Total	449,006	1,662,788	5,819,842	1,785,866	397,694	197,186	19,518	**10,331,900**	**100**
%	4.35	16.09	56.33	17.28	3.85	1.91	0.19	**100**	

2.5.3. Sectoral and livelihood impacts

Recognising that different types of rural livelihoods can have different objectives, strategies, and specific needs (Chapagain and Raizada, 2017), this section highlights impacts to some of the major rural sectors affected by the earthquake (Table 2.6).

2.5.3.1. Livestock farming

Livestock farming (such as raising beef cattle or raising sheep for wool) is New Zealand's largest primary industry (MPI, 2016a) (dairy cows considered separately in Section 2.5.3.2). Accordingly, the spatial extent of livestock farms is the dominant land use in the case study area, accounting for approximately 69% of land use, or 2.15 million ha (Table 2.4).

Overwhelmingly, the main concern for livestock farmers following the Kaikōura earthquake was addressing animal welfare issues, according to the interviews. Farmers had a strong connection with their livestock and wanted to ensure their well-being, and there were wider concerns livestock losses would negatively affect long-term farm health and business continuity (Dercon, 2004; Christiaensen and Subbara, 2005). Keeping the animals fed, hydrated, and secure were the key issues for North Canterbury livestock farmers. As over 95% of livestock diet on New Zealand farms relies on local pasture growth (Hodgson et al., 2005), the earthquake did not inhibit access to standard food sources, other than in a few cases where farms experienced surface ground damage due to fault rupture and landslides, making movement hazardous for people and livestock around those farms. A former North Canterbury farmer and interview participant points out that "you can't run stock if [the pasture] is full of

great crevasses." Additionally, the earthquake ground shaking resulted in burst water pipes and damage to water storage ponds and tanks on some North Canterbury farms (Cronshaw et al., 2016), inhibiting the use of these reserves for livestock drinking water. Livestock farmers also prioritised the fixing of damaged or destroyed pasture fences, in order to avoid losing livestock numbers.

On-farm impacts were compounded by the disruption to distributed infrastructure networks, particularly the road networks (Davies et al. 2017), isolating farms from necessary emergency supplies, social support networks. Business continuity and overall farm health was also affected by the isolation, as access to markets, processing plants, and specialist services was interrupted. Stevenson et al. (2017) report that this earthquake occurred approximately three weeks into cow mating season, and the damaged transportation infrastructure disrupted the ability of artificial insemination technicians to travel onto farms and ensure the following season's production. An interview participant explains that "if you don't get those things done within the right seasonal window that actually throws the farm out for a whole 12 months."

Impacts to livestock farmers from the Kaikōura earthquake compounded pre-existing drought impacts in the region. At the time of the earthquake, food and water for livestock was already scarce on most North Canterbury farms due to a pre-existing drought known as the Eastern South Island Drought (Hurunui District Council, 2015; MPI, 2017a; Stevenson et al., 2017). During times of drought, providing basic welfare needs for livestock can be difficult, as farmers have limited options to address drought impacts (Hurunui District Council, 2015; MPI, 2017a). Farmers will either need to have food and water brought to the farm, transport their animals off-farm to graze in pastures outside of the drought-affected region, or sell off livestock and repurchase animals in the future (Statistics New Zealand, 2006; MPI, 2017a). All of these options come with a cost for the farmer, and the lengthy response to the three year Eastern South Island Drought had exhausted the financial capabilities of many North Canterbury farmers, according to interviewees. A participant familiar with the situation explains that "nearly every farmer has exhausted his borrowing capacity with the land, [they] have used their financial reserves, they can't borrow any more money." In addition, none of these options were available to farmers given the access issues onto and off of farms caused by disruptions to the road network due to co-seismic landslides.

The combined drought and earthquake impacts impeded the ability of some farmers to provide for basic animal welfare needs. For example, a disrupted transportation infrastructure

network meant that farmers were unable to use their normal drought-coping mechanisms to move and sell off livestock, or have food delivered for livestock (Statistics New Zealand, 2006). Without sufficient feed, livestock weight can drop rapidly (Bierer et al., 1965), reducing farm returns (Stevenson et al., 2017). The water shortage caused by the drought was severely compounded on many farms by damage to water storage ponds and tanks due to ground shaking from the earthquake.

Reflecting on the drought and the earthquake, a clear theme emerged from all interviews. Managing the Eastern South Island Drought impacts were more important and challenging than managing the Kaikōura earthquake impacts for livestock farmers. While some farms were severely affected by the earthquake and had acute challenges, for the regional as a whole, the most detrimental aspect of the earthquake impacts seemed to be how they prevented livestock farmers from addressing the pre-existing drought impacts.

2.5.3.2. Dairy farming

New Zealand is the largest exporter of dairy products in the world (MPI, 2019), generating products such as milk and milk powder, butter, cheese, and infant formula. In the North Canterbury region, these dairy farms are typically located on flat terrain that can be irrigated in order to facilitate the growth of pasture and fodder crops used to feed the dairy herd (McHale, 2018), as is common internationally (Moran and Chamberlain, 2017).

Dairy farms faced the similar challenge of livestock welfare as their central priority following the Kaikōura earthquake, where disruption to water supply and fencing caused critical issues on many farms. In addition, the earthquake occurred during peak milking season, impacting both the production of milk on the farm and the collection of milk by tanker trucks. Damage to automated milking shed infrastructure, combined with disrupted electrical distribution networks, compromised the ability of many farmers to milk cows. Abruptly ceasing milking during lactation can lead to severe welfare issues for the livestock (e.g. mastitis) and to the cows ceasing lactation for the season, resulting in an immediate loss of revenue. Destroyed or damaged milking sheds forced some farmers to reduce milking from twice-a-day to once-a-day (Stevenson et al., 2017) or stop milking entirely (Bohny, 2017). At least 12 farms reportedly could not milk their herds in North Canterbury due to damaged milking shed infrastructure (Cronshaw et al., 2016). With herd sizes typically over 400 cows on most North Canterbury

farms (DairyNZ, 2017), it was essential to get these herds to another functional milking shed as soon as possible.

The disruption of regional road networks meant milk collection trucks could not access many farms. On-farm milk vats are typically only have capacity to store milk from approximately two milkings, so milk tanker access was critical. Additionally, disrupted electrical distribution networks meant some farms without power could not refrigerate their stored milk. This led to many North Canterbury dairy farms being required to dispose of up to 200,000 litres of milk daily (Hutching, 2016). Reports indicate that 22 Kaikōura District farms were inaccessible to tankers for over three weeks following the earthquake and so had to dispose of their milk (Cronshaw et al., 2016; Hutching, 2016; Stevenson et al., 2017).

While addressing these earthquake impacts, dairy farms in the case study region were also managing drought impacts. Similar to the situation with livestock farmers, the drought impacts resulted in livestock feed and water shortages on many North Canterbury dairy farms, and the earthquake impeded the ability of dairy farmers to bring livestock welfare needs onto the farm and address these impacts. An interview participant explains:

> [Poor animal welfare] can have catastrophic consequences for that farmer (…). Every calf, and their ability to milk next year, or [for the next] five years, has gone. So it's not just the consequences now, it's the long term consequences and people don't understand that. You lose a cow, you lose a calf, you lose a ewe, it's a production over time that you lose.

This inability to address animal welfare needs contributed to the decline of cow herds and had implications for the business continuity of North Canterbury dairy farms, and has also been observed internationally in similar rural earthquake settings (Kurukulasuriya and Rosenthal, 2003; Horridge et al., 2005; Howitt et al., 2017). North Canterbury dairy farms often milk their herds until April or May, however some farmers ceased milk production as early as December, resulting in months of lost productivity and farm income (Bohny, 2017).

While earthquake impacts may have affected farm infrastructure and the ability of dairy farmers to access markets in the short term, the combined and compounding effects of the earthquake and drought impacts on animal welfare (and therefore on long term farm health) was considered the biggest challenge to manage by most dairy farmers.

2.5.3.3. Horticulture

Horticultural farms account for 13.57% of the properties affected by the Kaikōura earthquake (viticulture is considered separately in Section 2.5.3.4), and land usage spans 14% (or 436,000 ha) of the northern South Island study area (Tables 2.3 and 2.4). Similar to the dairy sector, horticultural farms are typically located on flat, arable land, and is often irrigated.

Earthquake ground shaking caused some damage to existing crops due to isolated areas of liquefaction and lateral ground spreading in the North Canterbury and Marlborough regions (Cubrinovski et al., 2017). Surface expressions of earthquake fault rupturing in the area resulted in physical damage to crop rows, farm tracks, and fence lines. For example, up to 10 metres of horizontal ground displacement and 7 to 8 metres of vertical displacement was recorded along on the Kekerengu Fault (Cubrinovski et al., 2017). This affected the alignment of crop rows, impeding the use of machinery for tending to, and harvesting, crops. In some cases, land displacement also disrupted sophisticated irrigation networks that relied on precise gravity-fed mechanisms, however this was not widespread (Irrigation NZ, 2016), possibly because many New Zealand arable farmers use a spray and sprinkler type of irrigation system (Heiler, 2020).

Rather, the biggest irrigation concern for horticultural farms in North Canterbury was the condition of the sourced water, as well as changes to water table levels (Curbinovski et al., 2017). While most bore wells and irrigation pumps seemed to perform well following the ground shaking (Irrigation NZ, 2016), the water itself was found to be turbid and contaminated (Rutter et al., 2018), which, if used for irrigation, could clog and damage pumps, and contaminate crops, respectively. This change in water table levels also affected North Canterbury farms by subjecting them to drainage issues, the emergence of springs, sinkholes, localised flooding, and damage to stream banks and riparian areas (ECan, 2017a), all of which can impede normal farm operations.

The Kaikōura earthquake occurred at a time when, similarly to other sectors, horticultural farms were already pressured by the impacts of a pre-existing regional drought, and thus were in a fragile position with regards to the availability and use of water. Through physical damage to some planted crops, and by further limiting access to scarce water, the earthquake impacts made it more difficult for arable farmers to address the drought impacts.

2.5.3.4. Viticulture

The Marlborough District is home to 70% of the nation's wine industry (New Zealand Government, 2016), and, along with North Canterbury, was one of the worst affected regions by the earthquake (NEMA, 2020c). Roughly $1.6 billion NZD (~$1 billion USD) of wine was exported from the country in 2015 (New Zealand Government, 2016), making viticulture an important rural industry for the national economy. There are 604 viticulture farms in the northern South Island study area region, with 74.5% of these exposed to 'damaging' (MMI7) shaking or above by the Kaikōura earthquake (Table 2.3). This lead to a broad range of direct and indirect sector-specific impacts to these farms, including the surface damage and groundwater changes experienced by other crop farmers.

Ground shaking resulted in damage to vines, processing equipment, winery infrastructure, and structural damage to nearby critical infrastructure (such as roads and rail) on which vineyard value chain logistics relied (Cradock-Henry et al., 2018). Approximately 1,000 wine storage tanks in the region were damaged, accounting for nearly 60 million litres of storage capacity (and 20% of total available tanks in the region), resulting in a lack of storage capacity for the 2017 harvest (New Zealand Government, 2016; Nicholson, 2017) and a loss of income. Earlier structural earthquake resilience measures to wine tanks and associated systems following the 2013 Seddon earthquake in the Marlborough District probably lessened the extent and severity of damage experienced by some vineyards to the Kaikōura earthquake (Yazdanian et al., 2020). While over 5 million litres of wine are estimated to have been lost in the Marlborough District alone, this accounted for just 2% of total regional production (Nicholson, 2017).

The combination of these direct and indirect impacts of the earthquake required that wineries react immediately to mitigate losses (Cradock-Henry and Fountain, 2019). Smaller, mostly privately-owned, wineries had difficulties in managing these immediate impacts of the earthquake, compared with some of the larger wineries that were more readily able to bring in temporary storage, or access storage capacity in regions unaffected by the earthquake (Cradock-Henry and Fountain, 2019).

2.5.3.5. Tourism

The tourism industry in the northern South Island following the Kaikōura earthquake was mostly affected by disruption to the land transportation network (MacDonald et al., 2017). Multiple landslides, surface deformation, and inoperable bridges prevented land transportation north and south of Kaikōura township along State Highway 1 (Davies et al., 2017), a popular tourist corridor. This blocked access in to, out of, and within the region, stranding hundreds of tourists (plus thousands of locals), many of whom had to be evacuated by sea and air (Young, 2016).

Local and regional tourism expenditure dropped immediately (Cradock-Henry et al., 2018). Businesses that rely on this flow of customers (such as hotels, restaurants, tour operators, and gift shops) in the North Canterbury region saw an average 20% drop in earnings following the earthquake compared to November in the previous year, totalling losses of approximately $20 million NZD ($15.6 million USD) (New Zealand Government, 2017). This included an 80% drop in guest nights at commercial accommodations in the area (Statistics New Zealand, 2017). Direct losses to the tourism industry from the Kaikōura earthquake include damage to business infrastructure, and indirect losses include lower customer numbers, lost revenue, an inability to retain staff, and difficulties obtaining critical inputs and business supplies (Stevenson et al., 2017), as is commonly experienced after disasters (Rose, 2004).

While the earthquake impacts were severe at the local and regional levels, wider analysis suggested these impacts were largely confined to the North Canterbury region, and far less severe at the national level (New Zealand Government, 2017; Simmons, 2017; Stevenson et al., 2017; Cradock-Henry and Fountain, 2019). Work by Simmons (2017) shows that while tourism flow patterns shifted to avoid the region affected by the earthquake, the overall number of tourists within New Zealand stayed essentially the same. Research on tourism in the wine industry found similar results, showing that while some wineries experienced reduced visitor numbers to their tasting-rooms following the earthquake, other wineries benefitted from this change in tourism flow (Cradock-Henry and Fountain, 2019). So while acute effects were experienced in severely damaged or isolated areas in North Canterbury, the earthquake did not appreciably impact national tourist expenditure (New Zealand Government, 2017). Some North Canterbury tourism businesses were able to mitigate the economic losses caused by the earthquake by providing accommodation and meals for the regional influx of thousands of

construction workers involved in the rebuild of road networks, such as State Highway 1 (NCTIR, 2017).

Table 2.6 Summary of key impacts to major rural sectors caused by both the Eastern South Island Drought and 2016 Kaikōura earthquake.

Sector	Multi-hazard impacts	Resulting challenges	Mitigating factors
Livestock farming	Few water sources available; Changes to groundwater levels; Drought affected pasture growth and food source for livestock; Disrupted access on/off farms and within farms; Breeding seasons disrupted.	Drought impacts compounded by earthquake impacts; Deterioration in herd health given issues obtaining food/water supply for livestock; Value chains broken and inability to access markets; Interruption to breeding season causes immediate financial losses and affects future productivity; Repair and service technicians unable to access farms.	Existing drought resilience enhanced response and recovery to earthquake; Primary Industries Earthquake Relief Fund to cover costs for repairing uninsured farm infrastructure; Primary Industries Earthquake Recovery fund to support land use decisions; Skilled worker and volunteer programme to help with on-farm repairs.
Dairy	Farm infrastructure (such as milking sheds and storage tanks) damaged; Days to weeks before milk could be collected Changes to groundwater levels; from farm storage tanks; Disrupted access on/off farms and within farms; Breeding seasons disrupted.	Drought impacts compounded by earthquake impacts; Deterioration in herd health given issues obtaining food/water supply for livestock; Value chains broken and inability to access markets; Interruption to breeding season causes immediate financial losses and affects future productivity; Repair and service technicians unable to access farms.	Ability to use neighbour's functioning infrastructure; Legal ability to dump milk; Primary Industries Earthquake Relief Fund to cover costs for repairing uninsured farm infrastructure.
Viticulture	Damage to 20% of storage tanks in region; Difficulties bottling surviving wine; Difficulties getting wine out of region to markets; Disrupted access to winery tasting rooms; Changes to groundwater levels.	Lack of expected storage tank capacity affects industry ability to process 2017 season's harvest. Unable to repair damaged buildings.	Larger companies able to send wine out of region to be bottled and distributed; Primary Industries Earthquake Relief Fund to cover costs for repairing uninsured farm infrastructure; MPI led workshops to help viticulture

			farmers navigate Fund application processes.
Horticulture	Changes to groundwater levels (±3m across the South Island); Physical damage to farmland, crop-rows, farm tracks, and fence lines.	Harvesting the season's crops; Securing water for crops.	Primary Industries Earthquake Relief Fund to cover costs for repairing uninsured farm infrastructure.
Tourism	$20 million NZD in losses to regional tourism industry; 80% fewer guests in regional commercial accommodation; Cut in tourism flows; Tourism infrastructure damaged.	Lower customer numbers; Inability for industry to retain staff; Difficulties obtaining critical business inputs and supplies.	Accommodation and restaurant/catering businesses servicing influx of State Highway 1 constructions workers.

2.5.4. Vulnerable rural households and communities

Internationally, the demographic make-up of rural communities has been recognized as being complex and often highly contextually dependent (Caldwell et al., 1982; Williams and Cutchin, 2002; De Sherbinin et al., 2008). As noted in Sections 2.5.2 and 2.5.3 above, this is also true in New Zealand and specifically the case study region. This diversity creates a range of vulnerabilities and capacities amongst these communities. It's been well noted internationally and in New Zealand that these may go unregistered during and after disasters, and be underestimated by emergency managers (Bull-Kamanga et al., 2003; Hemingway and Priestley, 2006; Peek, 2008; Phibbs et al., 2014; Stough and Kang, 2015; Hay and Pascoe, 2019). To varying extents, interviewees noted this as an important issue during the response and recovery to the Kaikōura earthquake. A Canterbury-based emergency manager interview participant specialising in welfare lists the commonly vulnerable populations:

> Iwi (Māori tribes), disability, migrants and refugees, youth, elderly, they're probably the five [most vulnerable groups], and all of those groups are highly vulnerable groups in different ways. (…) Business [employees] might be another [vulnerable group].

One interviewed emergency manager suggests that the earthquake response needs of these vulnerable rural populations may sometimes be initially overlooked as they "don't necessarily have a strong Ministry behind them advocating for them."

This section presents the insights from the interviews and findings from available literature relating to the Kaikōura earthquake disaster, to examine the impacts on these groups that make up the rural population in the case study area.

2.5.4.1. Lifestyle blocks

An emerging and distinct section of the population residing in rural areas are those living on lifestyle blocks. Known internationally as "hobby farms," the New Zealand lifestyle block is a rural parcel of land typically <25 Ha which is not used as the primary income source for the household. In New Zealand, lifestyle blocks are typically not intensely farmed for business purposes, but used for recreational, domestic, or supplementary income usage; and are often but not always owned and/or occupied by older and/or retired residents. The average size of lifestyle blocks in the study area are 5.3 ha and make up approximately 53% (12,114 of 22,771) of the total number of properties in the region, despite only accounting for 2% of the spatial footprint (Tables 2.3 and 2.4).

This group has been found to have different values and priorities compared to other rural population groups in New Zealand, including higher expectations for external assistance following a disaster (Smith et al., 2011). Regular access to health care services was highlighted by one interviewee as being a potentially important issue for lifestyle block owners given the demographic makeup of this group, however road closures following the earthquake inhibited regional transportation and the ability of emergency medical care personnel to easily access many lifestyle block locations (no lives were reportedly lost due to this issue). Another key point made from the interviews was that while lifestyle block residents may reside in rural areas, they are not necessarily involved in or connected to local industries or social networks. This presents a unique challenge to rural response and recovery operations, in that the demographic make-up and disaster response needs of lifestyle block owners are very different to many other rural populations.

While emergency managers worldwide acknowledge the difficulties in effectively accommodating vulnerable populations (Bull-Kamanga et al., 2003; Peek, 2008), interview participants believe that, in rural New Zealand, there is a lack of systemic, higher level consideration on the matter. A CDEM participant familiar with national policy regarding vulnerable populations explains:

> There are multitudes of concerns around it, it's not just a CDEM one. We really care about when communities are vulnerable in any dimension, because that then impacts on people's abilities when something does happen. There's no strategic conversation about it, and it's not sure who should lead the conversation. (…) We're aware of it but not quite sure how to tackle it.

2.5.4.2. Independent but isolated

Rural regions are often characterised internationally as having high levels of resourcefulness (Bruneau et al., 2003) and emphasise self-reliance (Waugh, 2013), suggesting that temporary isolation may be manageable by most populations residing in these areas. Insights from the interviews strongly agreed with these findings from international literature, noting many rural residents in North Canterbury (particularly those working in the primary industries) exhibited a high degree of initial resilience towards the effects of isolation brought about by the co-seismic landsliding from the Kaikōura earthquake. However, interviews also show that within days to a week after the earthquake, many on-farm resources and capacities were being overwhelmed. In particular, locally available food and water reserves for livestock, already limited due to the drought, were being exhausted. Requests for assistance, especially in the form of resources to address animal welfare issues and repairs for agricultural infrastructure, were being made to the Emergency Operations Centre (EOC), the local headquarters for the government response.

There was a lack of understanding in the EOC on the earthquake (and drought) impacts and the context of what farmers were dealing with. An interviewee explains:

> [Farmer] requests were getting added to the back of a very long list, and [CDEM emergency managers] weren't able to sort the priorities for that list. Nobody had realized that cows stuck in Kaikōura, were, actually, a high priority, because it was a whole season's livelihood for that guy. It was animal welfare issues, they needed to get out. Lots of issues like that.

The urgency of some farmer needs was not initially understood by many emergency managers, and led to problems with prioritization of the response task list in the EOC. This was also highlighted as a problem according to a post-earthquake debrief commissioned by MPI and involving the agencies and organisations active in the rural response to the Kaikōura earthquake (HenleyHutchings, 2017). Needs that farmers considered to be a high priority for the response were downgraded to low or medium priority on the EOC task list. Another interviewee explains

that animal welfare needs should be put high "up in that priority list because not only is it an animal welfare issues but it is an economic issue."

These locally identified response priorities conflicted with the CDEM legislative mandate to first focus on life safety during a disaster response, before considering other aims (New Zealand Legislation, 2019). For example, the CDEM focus on life safety resulted in the closure of road access for many rural areas, in order to limit human and vehicle exposure to potential further landslides that might impact some roads. This decision caused severe impacts on the ability of the rural communities to respond to the disaster, and inhibited early recovery actions in these rural regions. The disruption to rural residents caused by one of these road cordons was so severe that, in some cases, rural residents took drastic measures to circumnavigate the road block. A rural interviewee explains:

> For the cordon on the Inland Kaikōura Road (…) no-one was allowed in or out, whether you lived there or not. That caused a real health and safety issue because, what had to happen then for people to be able to get in and out and carry on their daily lives and their recovery, they had to have what became nicknamed as the 'secret road.' So basically they just rigged up all the farm tracks, opened gates, cut a few holes in fences and just drove around the road [cordon]. (…) What that effectively meant was that we didn't know who was and wasn't in there because they weren't going through the cordon. So if there had been another major earthquake in there you wouldn't have known who was in there. (…) The first part of the secret road was just parallel to the cordon so there would be all these trucks and drivers and farm trucks and people driving on there and guys were standing on the cordon and they'd be giving them a wee wave and driving off.

As mentioned by the interviewee, the unofficial use of the 'secret road' was seen as necessary by some local populations in order to address their response needs and priorities. This same interviewee further commented that this road was even used by some services to the area, stating "the tankers weren't allowed in to deliver stock water, so they used the secret road." Similar behaviour has been documented for other rural disasters internationally (Wilkinson et al., 2016). Due to this poor understanding in the EOC by emergency management decision-makers on the impacts and context of the issues and challenges faced by farmers, liaisons from MPI were brought in approximately one week after the earthquake to help with this interface. An interviewee with MPI explains:

> We realized after about a week that [the response] was just not working [to meet the needs of farmers]. So it wasn't until we got [name omitted] and [name omitted] over into Civil Defence headquarters, who were very

> effective at explaining, almost translating, rural language into Civil Defence speak, that [EOC decision makers] realized these priorities and some action happened. So that was a learning.

These rural liaison officers were found to play a crucial role in helping contextualise the earthquake impacts and challenges faced by farmers to EOC emergency managers. The liaison officers were seen as a welcome addition to the EOC from the perspective of emergency managers, with one CDEM interviewee commenting:

> Liaison officers, we need to request liaison officers more. It's something we know we should do but we always tend to forget and I think most EOCs tend to forget to actually do that early on.

2.5.4.3. Migrant and transient workers in rural communities

Seasonal and temporary farm work in New Zealand tends to employ transient populations and migrants (Pomeroy, 2011a; Pomeroy, 2011b). Study participants interviewed following the Kaikōura earthquake agreed that these communities in North Canterbury were highly vulnerable to disaster impacts. An emergency manager describes the situation:

> There's also a real concern with most government agencies that work with people, and the Ministry for Primary Industries hasn't been a part of this conversation, that the rural community [is] changing, and it's changing because the way we're farming is changing. We have transient communities coming in [to rural regions] and doing [farm] work, and they are often from countries that aren't similar to New Zealand, so they might be from the [Pacific] Islands or Asia where obviously they don't get snow, for example. And because of the type of work they're doing, they're not able to integrate with the general community, because they wake up at 2am or 3am, and so therefore they go to bed at, I don't know, 7pm, and so the way their life is structured isn't conducive to any kind of integration. So they're seen as a very separate part of the community, with not much opportunity to create those networks that we advocate when you're building resilience. (…) We as government departments aren't particularly able to engage with those communities, [as] they are very mobile, [and] more often than not seem to be from countries where English is not their first language.

Accessing and engagement with seasonal and transient workers was considered a challenge by this interviewee following the Kaikōura earthquake, mirroring difficulties experienced by academic researchers in New Zealand (Wilson and Simmons, 2017), and more broadly following other disasters internationally (Morrow, 1999; Burke et al., 2012).

2.5.4.4. Iwi, people with disabilities, youth, elderly, and business employees

Iwi, people with disabilities, youth, elderly, and business employees are all population groups that were identified as being particularly vulnerable after the Kaikōura earthquake by interviewees. This aligns with international research on the specific needs of, and impacts experienced by Iwi (Kenney, 2019), people with disabilities (Hemingway and Priestley, 2006; Spence et al., 2007; Peek and Stough, 2010; Stough and Kang, 2015), youth (Peek, 2008; Peek and Stough, 2010; Ronoh et al., 2015), the elderly (McGuire et al., 2007), and business employees (Drabek, 2000) following a disaster. However, interview participants and other published research related to this earthquake to date do not elaborate on the specific issues these populations experienced in the North Canterbury post-earthquake context, indicating a notable gap in knowledge.

2.5.5. Disaster in a multi-hazard environment

When interviewed on the impacts of the Kaikōura earthquake, all North Canterbury based interview participants (see Section 2.5.3) repeatedly brought up the existence of a drought that had been affecting North Canterbury for three years leading up to the earthquake. The regional scope and severity of the drought was nationally acknowledged on 22 February 2015, when MPI classified the Eastern South Island Drought as a 'medium scale adverse event,' triggering recovery measures and funds aimed at helping farmers and rural communities (MPI, 2017a). The MPI classification takes into account physical measurements of soil dryness (through the New Zealand Drought Index), the scale of the physical impacts, the ability of local communities and economies to cope, and the availability of mitigation options available to farmers. With dry climatic and soil conditions continuing for months after MPI's recognition of the issue, the Hurunui District Council would release an update on the drought conditions, on 24 December 2015, which stated "the majority of the District has received less than 50% of average rainfall over the last 18 months. The severity of the drought is random across the district with localised areas more serious than others" (Hurunui District Council, 2015). Plots of soil moisture deficit (Figure 2.3) indicate the location of dry soils across New Zealand at the start of summer historically, at the start of summer in January 2016 (approximately 10 months before the Kaikōura earthquake), and at the start of summer in January 2017 (approximately 1.5

months after the Kaikōura earthquake). These dry soil conditions correlate with lower than average groundwater levels measured across Canterbury in 2016 (ECan, 2017b). By the time MPI's official 'medium scale adverse event' declaration for the drought ended on 31 December 2016, soil moisture conditions in the North Canterbury region were starting to improve for farmers (Figure 2.3), however many were still suffering from, and actively managing the negative medium- and long-term impacts of the drought, according to interviews. As noted in the above sections, the combined effects of the social, economic, and ecosystem impacts created by years of drought conditions in North Canterbury were compounded by impacts of the Kaikōura earthquake.

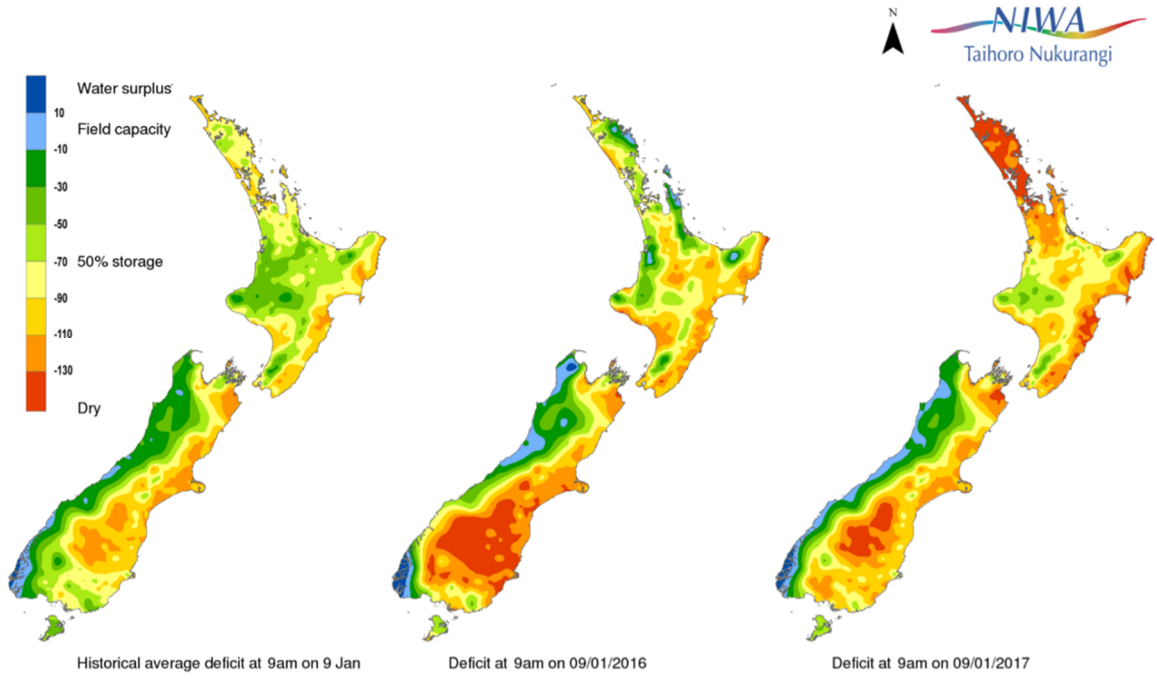

Figure 2.3 Comparison of soil moisture deficit on 9 January historically, on 9 January 2016, and on 9 January 2017. From ECan (2017b) using data from NIWA (https://niwa.co.nz/).

The drought limited the local resources that were necessary to adequately provide food and water to livestock, as well as to grow crops, forcing many farmers to take additional bank loans in order to remain solvent. Therefore, when the earthquake occurred, many farmers had already exhausted their lines of credit with the banks. The inability to borrow more money from banks to address impacts from the earthquake was a large financial burden which stemmed directly from the drought, and an additional source of stress for farmers.

Mental health issues generated by the long-term drought were an important issue at the time the earthquake occurred. An interview participant with a background in farming notes that "the first thing about a drought is it's insidious. You never know when it's over, and it's the sheer drudgery of hand feeding stock every day." These environmental and financial drought impacts appeared to have flow on effects on the physical and psychological well-being of farming families and farming communities. Anecdotal evidence from multiple interviews indicate that the three years of drought negatively affected the mental health of farmers and other agribusiness workers to the point of interfering with family relationships. An interview participant who is well networked in the region, commented:

> The drought particularly has also been hard on relationships, and we've had… I can think of three or four marriage breakups which, arguably, [were] caused by constant pressure. Just wears you down.

The drought had such severe negative effects in North Canterbury that a Drought Relief Committee, chaired by the Mayor of the Hurunui District, had been established in April 2014 (https://www.hurunui.govt.nz/) to deal with the professional and social consequences produced by the ongoing drought. Establishing the Drought Relief Committee approximately 2.5 years before the November 2016 Kaikōura earthquake proved essential in providing a pre-established regional network of formal and informal relationships. These were heavily relied upon during the earthquake response:

> We asked [the Mayor] if he would chair a Hurunui District Committee, which he was happy to do. And that [Drought Relief Committee] went on for the whole duration [of the drought], about three years. (…) We were really nicely set up with that group when the earthquake happened, because they knew each other, they had the confidence to do things, and that was the core of what then became the Earthquake Committee.

In this sense, the social networks put in place to address the drought helped lessen the overall disaster impacts of the earthquake. All the interview participants familiar with this committee considered it a positive existence. These pre-existing relationships proved to be vital in allowing for effective and efficient working relationships and communication between, and within, communities and agencies involved in the earthquake response and recovery. The steps taken towards drought resilience in the region became, in turn, a source of earthquake resilience. An interview participant from MPI says "we've just realised the value of having these local committees and getting those going."

The value of maintaining the strong community bonds generated by this local committee is clear given the high level of public support for the continuation of regular meetings, even during times of non-emergency. A regional government policy analyst explains:

> [The rural population is] now saying "we want to keep this [committee] going because it's a really nice forum to just keep in touch with what we're doing, and keep that community spirit going and keeping events going." And MPI, after the funding specifically for the drought had finished, (…) gave (…) quite a large funding to just keep the resilience out there. (…) So they've actually got the ability to keep functioning for quite some time on that basis, and they're doing really nicely.

It is also possible that other drought-coping mechanisms helped lessen the earthquake impacts to rural North Canterbury. Farmers needed to sell off livestock during the drought, as it becomes challenging to provide adequate food and water, and this likely reduced the number of livestock (and thus exposure) in North Canterbury.

2.5.6. Inter-agency coordination

The scale of the Kaikōura earthquake generated a national level of response. Many groups and organisations, at all levels, participated in the response and recovery activities required by this earthquake. This section explores the strategic coordination of these actors, the horizontal and vertical coordination that occurred (or not) with responding agencies, organisations, and individuals following the earthquake, and instances where positive and negative issues with organisational coordination and understanding may have occurred during response and recovery activities.

2.5.6.1. Strategic coordination of earthquake response and recovery

As described in Section 2.3, multiple organisations and agencies are involved in the response and recovery to rural earthquakes in New Zealand, and strategic coordination of the response is dictated by the regions affected by the disaster. In the case of the Kaikōura earthquake, the over-all response was led by the regional Canterbury, Marlborough, and Wellington CDEM Groups, supported nationally by MCDEM although a national state of emergency was not declared (MCDEM, 2017b). On the South Island, states of emergency were

declared in the Kaikōura and Hurunui Districts, followed by a Canterbury CDEM Group wide declaration, and for a few hours the city of Dunedin had also officially declared an emergency (DPMC, 2017). Despite not officially declaring states of emergency, the Marlborough, Nelson-Tasman, and Wellington CDEM Groups were activated for days to weeks following the earthquake in order to manage the considerable damage to infrastructure and assets in their respective regions (MCDEM, 2017; NEMA, 2020d). The additional legislative powers granted to emergency managers by these declarations enabled response and recovery operations in some cases, and inhibited it in others (WREMO, 2017). Multiple local emergency operations centres (EOCs) and regional emergency coordination centres (ECCs) were activated and staffed by the government, as well as the national coordination centre (NCC) in the capital city. Some EOCs and ECCs were set up to respond to the earthquake, but others were primarily set up to respond to co-seismic hazards caused by the earthquake. According to a MCDEM post-event report "most ECCs around the country were activated for short periods to respond to the tsunami event" (MCDEM, 2017b), while others activated in response to the potential that a severe rainfall event might further trigger landsliding (WREMO, 2017). The relationship between the EOCs, ECCs, and NCC that activated following the earthquake can be seen in Figure 2.4. The ECCs that only activated briefly (for a matter of hours) to potentially manage the tsunami threat are not included in the figure.

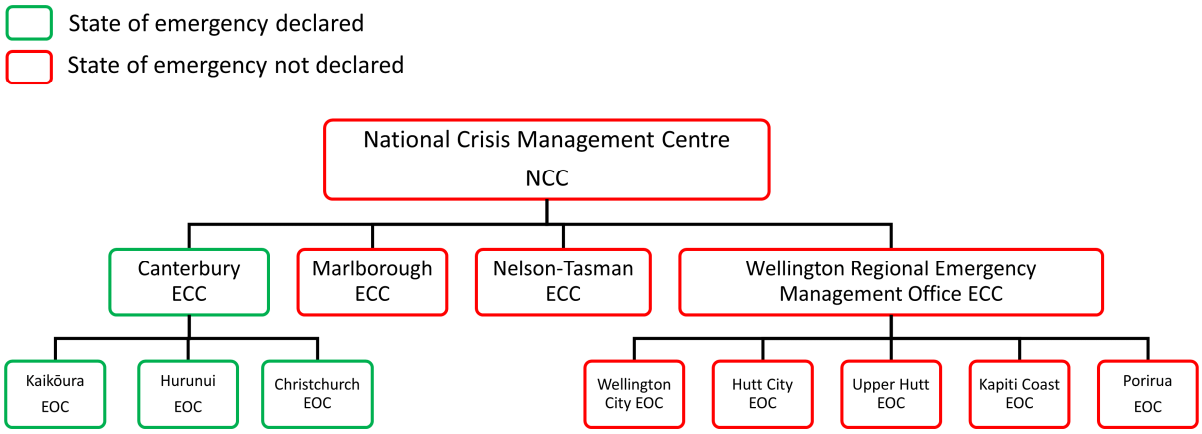

Figure 2.4 Hierarchy of the local emergency operation centres (EOCs), regional emergency coordination centres (ECCs), and national coordination centre (NCC) that activated in response to the 2016 Kaikōura earthquake and co-seismic hazards.

The CDEM response phase to the earthquake ended on 9 December 2016, with the end of the local and regional declared states of emergency (NEMA, 2020d). At this point, strategic oversight of central government's role and support of recovery in rural regions was through the

National Recovery Office, which facilitated the establishment of several governance arrangements, such as the Transport Corridor Oversight Group, the Kaikōura Harbour Restoration Steering Group, the Kaikōura (township) Rebuild Steering Group, and the National Social Recovery Coordination Group (NEMA, 2020f). The National Social Recovery Coordination Group, for example, had responsibility for managing welfare services support for affected populations, and actively worked with the Canterbury CDEM Group and local recovery managers in the Hurunui, Kaikōura, and Marlborough Districts (NEMA, 2020f). The Ministry of Health had oversight of delivering psychosocial support, and was supported by the Ministry of Social Development and the Canterbury District Health Boards (Gluckman, 2016).

Strategic coordination of the primary industries sector was the responsibility of MPI, who is mandated to guide government decisions on recovery assistance under the Primary Sector Recovery Policy (MPI, 2016b). Recovery assistance from MPI included rural recovery coordinators, skilled workers and volunteers, funding for rural organisations (such as the Rural Support Trusts and TeamAg), and funding available directly for farmers (through the Primary Industry Earthquake Relief Fund and the Primary Industries Earthquake Recovery Fund) (MPI, 2017a; NEMA, 2020e).

Notably, while many rural organisations (such as Federated Farmers, the Rural Support Trust, and FarmStrong) and government-led organisations (such as MPI) actively addressed the disaster response and recovery needs of farmers and other agribusiness owners (NEMA, 2020e), a number of other rural population groups were not represented by these primary industry-focused organisations following the earthquake. One example is lifestyle block owners (see Section 2.5.4.3). While this appears to be undocumented for the Kaikōura earthquake, at least in the public domain, gaps and unintended omissions in response and recovery coordination may have resulted in some rural North Canterbury populations suffering disproportionately more than others, as many do not seem to have the strong backing and support provided to farmers from both MPI and private industry. Contextual differences in disaster response needs and priorities between farming and non-farming organisations in rural New Zealand has previously been observed by Whitman et al. (2013).

2.5.6.2. Horizontal coordination

Coordination of response and recovery activities and actors at the local level in rural North Canterbury was found to be complex and consist of three distinct facets, which this section describes in turn. First, the coordination between rural organisations is considered. Second, this section analyses the coordination between MPI and CDEM, arguably the two most important government agencies involved in the response and recovery to the Kaikōura earthquake. Finally, the interaction between both rural organisations and the government response is described.

Between rural organisations

Coordination between rural organisations was found to have both positive and negative elements. In some ways, social connectivity of rural populations was increased due to the interactions and coordination of rural organisations. Often with the help of funding from private businesses and central government (MPI, 2017a), rural groups were able to increase levels of community bonding following the earthquake. The head of a North Canterbury rural organisation explains:

> Well I think one of the main things that helped was the fact that [rural organisations] ran a lot of field days where they tried to teach farmers strategies to get them through. For example one of them was a body conditioning [workshop for livestock]. (…) There were a lot of those days (…) and always after we had a BBQ and a few beers.

Public barbeques, veterinary demonstrations, farm strategy lessons, and budgeting lessons were among the ways in which both rural organisations were able to work together and positively contribute to social connectivity (and mental health) in rural areas. This was achieved largely through self-organization of rural groups, and in turn helped increase levels of community resilience.

Poor coordination between other rural organisations was found to be a source of confusion and frustration for impacted individuals in the Hurunui and Kaikōura Districts, leaving many unsure where to turn for help. Multiple agencies meant the presence of multiple distinct organisational structures and reporting mechanisms, making it difficult for those affected by the earthquake to utilise or identify a single, unified, source of information, resulting in occasional duplicated, outdated, or inconsistent messaging. This frustration can be illustrated through the experiences of one rural organisation in their attempts to assess earthquake impacts

at a household level, a task partially completed (though not communicated) by multiple agencies, organisations and volunteer groups. An interviewee explains:

> One of the biggest headaches we had was people like stock agents and fertilizer companies and things, they go and check on their clients but they wouldn't check on the other person next door, they'd just go and see their clients. So you'd have roads in places where three people had been visited and three people hadn't. So you are trying to do a whole sweep to make sure people are alright and for some poor buggers you were the sixth person up the drive (…) and they were getting pretty sick of people. But then you go to the next person and they hadn't seen a soul.

This patchy network of surveys undertaken by a variety of different organisations suggests that, firstly, there was a clear need for impact assessments at a household level. Secondly, in the void of action by responding government agencies, rural organisations and groups will step forward and attempt to address these gaps (see section 2.6.3. for further discussion). However, this lack of coordination among rural organisations performing welfare surveys was a preventable source of stress and an additional time burden for the local residents. While there is an important need for individual-level welfare data during a response, it is important to not overload residents actively suffering from traumatic experiences (Beaven et al., 2016). This presents a dilemma to emergency managers, as certain individuals and families benefit from regular check-ins, whereas others prefer uninterrupted time to process the events. This dilemma is greatly compounded when a number of groups conduct similar surveys with comparable welfare questions.

Between MPI and CDEM

Interview participants from both CDEM and MPI agencies were willing and intent on working together in response to this earthquake. However, there were difficulties in coordination between these two groups, arguably the two most important government agencies involved in the response. In part, this can be attributed to differing assumptions made by both agencies. For example, CDEM expected MPI, a government agency present and active in rural areas before, during, and after this and other events, to be the united rural voice for local operations. What clearly emerged from the interviews was the need for a rural representative to provide leadership, advocacy, and guidance on rural issues, as CDEM lacks the mechanisms to fully incorporate the wide range of grassroots response initiatives that are established after rural disasters. One emergency manager with CDEM explains:

> When the community spontaneously organises [to respond to an event] we're not able to capture that because we're too structured and rigid to be able to morph, and so we piss people off. Basically, what we needed is some way of capturing what they were doing, and pulling it into our process, amalgamating it with our process.

One CDEM participant interviewed stated that "we kind of assumed that MPI would act as a conduit and our advocate for that dimension of the rural sector." However, MPI's view is that leadership and coordination should come from within the affected communities. While they recognized the importance of these roles, they did not see their role as providing that. One MPI participant in the study explained that:

> We're happy to support, but MPI's philosophy is that [rural sector coordination] is best led by the [rural] people involved. We provide the secretarial support, we're on all the calls, we take messages back and forth, and answer questions and things like that. It's best when it's their committee, not ours.

There was discord and a lack of common understanding of the roles and responsibilities between CDEM Groups and MPI with respect to the rural response and early recovery. While operational terminology is consistent through emergency managers' use of the standardized Coordinated Incident Management System (CIMS) terminology, higher-level common understanding of complex issues remained poor. For example, even amongst government agencies responding to this rural earthquake, not all agreed on the definition of 'rural.' Both MPI and CDEM had trouble with their operational interfacing due to each agency's separate understanding of what was this meant. One CDEM worker explains:

> I think the other thing we slightly struggle with is, what exactly is meant by "the rural sector," and recognising that MPI, for them, "rural" are primary producers and for us "rural" means anyone who's not living in an urban setting. We don't care how you earn your money, if you live in a rural area, the hazards and the risks are the same. (…) MPI have said well we don't [worry about] peri-urban communities [and] small lifestyle blocks, because they don't earn their income from [farming practices]. Well, for us, their risks actually sit in "rural" not in "urban," and we assumed [MPI] did do that.

For day-to-day operations, MPI typically works with people and groups that earn income through the primary industries. This covers most of those living and working in rural communities, but not all. There are populations living and working in rural areas who have little to no interaction with MPI (see Section 2.5.4). The scope of people and groups that MPI works with on a normal basis is different from what CDEM originally expected and assumed.

The coordination issues apparent between these two agencies is reflected within a review of the Kaikōura earthquake response and early recovery commissioned by MPI and delivered by a private consulting firm 7 months after the earthquake (in June 2017). The review was derived from a de-brief workshop involving organisations and stakeholders who were active in the response to the earthquake, outlines key pressure points that arose during the response and recovery to the earthquake, and provides recommendations (HenleyHutchings, 2017). Some of the key pressure points noted in this after-action report include poor understanding of rural needs by urban-based emergency managers, leadership and communication issues, and poor interfacing between CDEM and MPI's TeamAg.

Enhancing the coordination between MPI and CDEM was a recognised goal for both agencies. An emergency manager with CDEM describes the disconnect in their working relationship with MPI: "I think we're really struggling to come to grips with how that actually should work." A valuable and beneficial working relationship between the two agencies was arguably eventually achieved and recognized by interview participants from both agencies, aided in part by the establishment of liaisons in the EOC (see Section 2.5.6). An emergency manager with CDEM explains how this was recognised as an encouraging outcome:

> I think successes for [CDEM] in the Hurunui and Kaikōura [Districts] were the likes of when the MPI people did come in [to the EOC], and were working with us, and they were working with us not against us which was really useful.

Between rural organisations and government agencies

Poor organisational interfacing between rural organisations and the CDEM-led government response led to difficulties in cooperation. Findings show that this led to some rural populations being inadvertently overlooked. Before public road access was re-established connecting the Hurunui and Kaikōura Districts to the outside world, essential supplies and resources were brought in by the New Zealand Defence Force using a convoy of trucks that were able to navigate a rugged and otherwise impassable access route they had created. This convoy brought in outside goods for those who could not leave the region to re-supply themselves as needed. Initially, it ran non-stop from its origin on the southern (Christchurch) side of the road closures, and ran all the way to the Kaikōura township. Some of the goods included within the convoy were intended for use by impacted farmers, who were located in the smaller communities along the route through which the convoy passed but did not actually

stop. These goods were specialised and intended to address livestock welfare needs. Instead, these goods ended up in the Kaikōura township. This misunderstanding of the convoy logistics caused tension between government agencies and the rural organisation attempting to deliver necessary aid to those rural areas. A coordinator from the rural organisation explains:

> After about four or five days we started getting calls from the farmers in [rural] Kaikōura and people in the hinterland not having anything, and we were trying to figure out why the hell that was, because there was that much stuff going in! We had a massive shipment of stuff going out to dairy farmers, from Southland, that they needed. And so when one of our contractors was down at Kaikōura with his chopper and I said "this [shipment] is coming, keep an eye out for it," and just as well I did because it was just picked up [from the Kaikōura depot] by the military to be taken into Kaikōura township and he's going "whoa whoa that's not for the town," [and they responded] "oh yes it is, everything goes to town." So mastitis ointments, a list of dairy [farm] products, and animal health products, why the hell would that be going to Kaikōura township?

Eventually this issue was resolved, and the convoy began making regular stops in two of the small communities along the way to the Kaikōura township. However, this took more than a week to establish after the earthquake, meaning that some isolated farms, who could not even access the Kaikōura township, went without aid for at least that long.

Coordination between response and recovery activities between rural organisations and the CDEM-led government response was also found to be hampered by differing perspectives on 'risk to life' versus 'risk to long term production' between often urban-based emergency managers and rural residents and organisations. In this case study, the risk to life was relatively low, whereas the risk to long term production (and by extension business, family, and community wellbeing) for the 10,000 farm businesses subjected to strong (MMI 5) or higher ground motion (Table 2.3) was high. This stems in part from the strong link in rural areas between individuals, agribusiness, and communities, as many rural communities revolve around local primary industries and associated services (Janssen, 2006). Unlike many urban based jobs, most farmers do not leave their work site at the end of the day. Their home and their work site are directly linked, by the fact that they are often the same physical location. It follows that increasing the health of local agribusinesses will in turn better conditions within the average rural North Canterbury household, as has been shown internationally (Khan et al., 2009). Therefore rural households in the case study region were highly vulnerable to the negative

effects from disturbances to the farming industry. This intimate link between rural farming business and home was not well understood by emergency managers.

To address coordination and integration issues between the rural sector and the CDEM response mechanism, the Canterbury Primary Industries Adverse Events Cluster Group was created, to be led and represented by a Rural Advisory Group (RAG). This group was created in response to experiences with poor coordination during the Kaikōura earthquake (Deavoll, 2018) and includes representation from government (such as MPI, CDEM, and Councils), private sector groups (such as Beef + Lamb and DairyNZ), and other rural organisations (such as Federated Farmers, Rural Support Trust, and the Society for the Prevention of Cruelty to Animals). Every effort at coordinating the rural sector before a future disaster was seen as positive by interview participants, and MPI is now facilitating the creation of similar groups throughout New Zealand to help with rural responses to disasters (Caddick, 2018). As one emergency manager explains, there is "nothing worse than trying to start something during an emergency." Another participant, an emergency manager with CDEM, describes the daunting task of interfacing CDEM with all of the rural groups and individuals during a response. According to the participant, the RAG will enable a more coordinated rural disaster response in the future:

> We can't form a relationship with all these different forms of rural people, (…) so we need a mechanism that brings them together, so that we can have that relationship (…), and that's what the Rural Advisory Group will hopefully do.

While the RAG is poised to interface and represent much of the rural sector, the organisations involved currently show a tendency towards agribusinesses and farm owner representation. The goal of the RAG is to integrate the rural sector with local government and CDEM, to "represent farmers and growers in future events" according to an early media release (MPI, 2018). It is clearly focused on primary industries, but it is unclear who, if anyone, will represent the needs of the more vulnerable rural populations (such as those described in Section 2.5.4). There are currently no organisations within the RAG which can directly speak on behalf of these populations, which often require the most help during and after a disaster.

Ultimately, despite the confusion and challenges in coordinating the earthquake response within the rural sector, all the emergency management participants interviewed believe the response to the earthquake went relatively well. A CDEM interview participant involved in the response explains:

> The fact is in a response it is chaotic, full stop. You don't have an orderly response. So are [the general public] interpreting that as meaning the structures weren't working, rather than going well? In a response it is always chaotic, but actually the [CDEM] structures did end up working quite well.

Other interview participants, who were not directly involved in the CDEM response mechanism, had less positive views.

2.5.6.3. Vertical coordination

This earthquake revealed how difficult it can be to integrate informal local response arrangements (often established in an ad-hoc manner immediately after the event), into the formal national response structures, spanning across multiple different districts and three regions within New Zealand. As the national level response to this earthquake involved many organisations at different levels of government, each of the groups' individual perspectives and operational procedures were also necessarily involved. Results from this work agree with Cradock-Henry et al. (2018) who showed that grassroots volunteer initiatives following the Kaikōura earthquake were an important part of the disaster response and recovery, but typically lacked the coordinated structures that facilitate integration into the wider government-led response efforts. The interaction and vertical coordination between these and other groups was not always smooth.

Response coordination weaknesses in vertical coordination become evident, for example, when considering shared informational databases. According to the MPI post-event debrief (HenleyHutchings, 2017), recurring challenges between national and local organisations arose from differences in technical competencies, access to and training in the use of specific computer programs, and logistical issues over data sharing agreements and file transfers. Ethical issues were also raised over who had access to data containing personal and possibly sensitive information, and whether participants' initial consent applied to the various iterations of the database accessed by subsequent additional agencies. One interviewee questioned whether information collected in the early days of the response by a small, intimate, neighbourhood-level group should be included into an official government database without re-obtaining consent from the participants, as well as questioned what happens to the data after the response ends. The procedure and mechanisms for handling information and personal data was not well defined, if at all, and was not clearly communicated to participants or responders.

Additionally, in order for the shared informational database to work within the respective systems (and siloes) of the different responding agencies, very different identification details were needed for each entry. An interviewee describes their experience as a member of a rural organisation, attempting to integrate their database with the databases of regional and national level organisations during the response:

> I had to laugh because the CDEMs got all upset with our database because they couldn't use it. Because it was based on local knowledge, it was the names of people and the names of properties as we know it, as the rural community knows it. Of course the councils had to have RAPID numbers, and so they were going "well what are the RAPID numbers?" We don't know what the bloody RAPID numbers are, [those surveyed] don't know what their RAPID number is, we just know it's "the Browns up the top end of such and such." (…) When they got the database, they expected it to be in a form that they could instantly use, which was quite interesting. Then of course, the military boys on top, they wanted all the GPS coordinates. So [the database needed] names for the [local rural organisations], RAPID numbers for the CDEM Groups and Councils, and GPS coordinates for the military.

The Rural Address Property Identification (RAPID) system was designed to be a standard numbering system for rural properties in New Zealand (New Zealand Government, 2011), however this system was clearly unknown and not used by rural organisations and individuals. This example shows how different organisations at different levels required specific information to use within their own databases, and this lead to tension between the organisations who collected and shared the data.

Another barrier to effective vertical coordination between agencies following the earthquake can be found in the after-action report published by MCDEM from its national-level perspective. While the report noted issues with targeted emergency warning systems and general communication with affected regions, issues staffing the National Crisis Management Centre (the coordination centre for the national level response to disasters) was a key factor affecting initial vertical coordination between the capital and all other levels of the response (MCDEM, 2017b). Specifically, there were difficulties in activating the National Crisis Management Centre amidst the moderate shaking experienced in the capital by the Kaikōura earthquake.

2.6. Discussion

This section highlights the importance of context when considering the impacts and implications of the Kaikōura earthquake to rural communities and industries. It does this first through a discussion of the ways in which New Zealand's status as high-income nation affected the level of impact caused by the earthquake, then through a discussion on how the multi-hazard context in which the earthquake occurred affected the challenges and opportunities experienced in rural New Zealand. Finally, the interagency coordination between and within the response and recovery actors and rural populations is commented on.

2.6.1. Rural earthquake disasters in high-income nations

This work shows that disaster impacts to rural sectors and communities from the Kaikōura earthquake can have very different characteristics when compared to rural earthquakes impacts reported in low-income nations. While loss to life was extremely low given the magnitude of the earthquake, the economic cost of the Kaikōura earthquake disaster was high, reflecting a trend commonly reported for disasters in high-income nations (McEntire and Mathis, 2007). New Zealand's high economic reliance on the primary industries ensures financial and political incentives for a strong response and recovery to rural earthquakes. New Zealand benefits from strong governance structures and a social and economic wealth that allows disasters to be managed in ways that may not be available in low-income nations (OECD, 2020a). This wealth allows New Zealand to allocate funds towards disaster risk reduction, readiness, response, and recovery measures. Resources invested by MPI into primary sector recovery packages following the earthquake were found to be an important source of aid for North Canterbury farmers and supported rural business continuity. MPI efforts to manage the pre-existing drought also had the added effect of increasing social connectivity and strengthening rural networks, both of which were found to directly facilitate earthquake response and recovery actions in this case study. Access to options for risk-transfer (i.e. insurance) have been shown to reduce disaster risk (Teh, 2017), but may not be readily available or affordable in low-income nations (Kumar, 2017). Specialised government agencies in New Zealand (such as the EQC), and a robust critical infrastructure sector, can facilitate an effective disaster response in rural areas (Parajuli and Haynes, 2018). In addition to resources, disaster

response capacities in New Zealand were found to be high. A robust, highly trained, and experienced emergency management sector, coupled with a strong Ministry backing the primary sector industries and large agribusinesses all contributed time, personnel, and funds to earthquake response and recovery efforts. The resources and capacities available in New Zealand effectively reduced rural vulnerability to disasters.

The ground shaking and surface fault ruptures were problematic in the case study region, causing physical damage to sophisticated farm equipment, agricultural infrastructure, and critical infrastructure. However, with regards to the earthquake impacts, findings show that it was the secondary effects of these impacts that were found to be the most disruptive and impactful to the case study region. A disruption to the electrical network meant that North Canterbury dairy farmers, for example, could not milk their large herds of cows without the use of automatic milking sheds. A damaged road network effectively severed rural value chains and access to global markets. As most farms in New Zealand are geared toward commercial production (rather than subsistence), this was an important concern with regards to earthquake impacts. Spatial impacts (i.e. physical damage to farm property) was found to be more readily managed when compared to the temporal impacts (i.e. implication of poor animal welfare on long term farm health).

This study highlights the important role of context in disaster impacts. This applies to differences between low- and high-income nations, but also to variations within a single country. The 2010 Darfield and 2016 Kaikōura earthquakes were both based in rural Canterbury, yet were fundamentally different disasters. The Darfield earthquake occurred on flat glacio-fluvial plains in central Canterbury, an area of high-intensity arable and dairy farming (Quigley et al., 2016), and had very low disaster risk to landslides. Meanwhile, the secondary effects of the ground shaking, such as the loss of critical infrastructure due largely to co-seismic landsliding, was a key issue following the Kaikōura earthquake. The resulting physical isolation and disruption to value chains experienced by many North Canterbury farms after the Kaikōura earthquake was not experienced by the central Canterbury farms affected by the Darfield earthquake. The underlying drivers of disaster risk were different, even between two rural disasters within Canterbury.

2.6.2. Multi-hazard context

This case study also highlights the importance of understanding how a multi-hazard context contributes to disaster risk in rural areas. Multiple factors and drivers of disaster risk contributed to the severity of the impacts felt in rural areas following the Kaikōura earthquake. An existing drought and pre-stressed natural environment, financial hardships, an extreme weather forecast, and the seasonal farming cycle all contributed to increasing the severity of the earthquake impacts.

The presence of both a drought and large-scale earthquake affecting the same people, in the same landscape, and at the same time, allows for a direct comparison between the levels of impact caused by each of these natural hazards. While that was not the original intent of this study, the role of the drought in rural North Canterbury immediately became clear. One rural interview participant did not mince words when stating that the drought "had a far bigger impact [on rural regions] than the earthquake." The drought impacts were considered worse than the earthquake impacts because of the associated long-term consequences and financial implications. An interviewee from a rural organisation explains the long-term financial impacts of the drought:

> Put it this way, [the drought] is over in terms of moisture deficit. The ground is full of water, we've had a very wet winter. But the financial effects will go on for three or four years.

Despite the larger media and government presence following the earthquake, the effects of the multi-year drought on rural populations were generally considered worse by interview participants than the impacts generated by the earthquake. This multi-hazard setting compounded and exacerbated the existing drivers of disaster risk following the Kaikōura earthquake. A key finding of this study was that the multi-hazard context (i.e. pre-existing drought) was considered worse than the actual event (i.e. earthquake) which triggered the disaster.

However, this case study also shows that a multi-hazard setting can, in some ways, be beneficial. For example, the networks and committees formed locally in the years before the earthquake, originally aimed at increasing local drought resilience, had the additional effect of increasing local earthquake resilience. This benefit was well documented, and is reinforced by the local appetite to maintain some of these professional committees well after the disaster is

over. Professional networks, established before the earthquake, provided an increased level of community resilience that was able to address multiple types of natural hazards.

2.6.3. Inter-agency coordination

Previous work in New Zealand has discussed the need for a more coordinated organisational response to disasters (Paton et al., 1998). In the rural context, this would include government agencies, private businesses, rural organisations, and other smaller community groups. Paton et al. (1998) cited a lack of organisational responsibility for coordination, inadequate inter-agency communication, and a lack of managerial leadership as key issues needing to be addressed. While national guiding legislation has changed and arguably been improved since the publication of the Paton et al. (1998) research article (primarily through the CDEM Act 2002 and subsequent amendments), case study results support findings from Basher (2016), who argues that these themes remain current challenges for New Zealand disaster reduction, readiness, response, and recovery planning and practices, despite a world leading national legislation for disaster risk reduction (IFRC, 2014).

In this case study context, the coordination between MPI and CDEM was one of the more important inter-agency links that related to success of the earthquake response and recovery. While MPI is one of the largest organisations active in the rural sector during business-as-usual times, CDEM is one of the largest organisations (and mandated lead agency) active during disaster response. These two organisations must be well interfaced for effective response and recovery operations to be possible in the rural context. The poor early interface between MPI and CDEM reveals a lack of deep understanding between each organisation relating to roles and responsibilities in the rural space. This was exposed through some incorrect assumptions made early in the response, on both sides.

Part of the disconnect between these agencies can be attributed to the way they (and the rest of government) have been structured to deal with disaster risk governance. The implementation of national level policies depends on local interpretation, and this has been shown to be an on-going challenge in the New Zealand context (Basher, 2016; Saunders et al., 2020). It can be expected that different individuals in different organisations will interpret the same piece of legislation in different ways. Each agency has their own role and legislative mandate, which may or may not overlap in certain situations. Given the nature of disaster

response, a chaotic environment between organisations is to be expected; however, these two leading actors in a rural disaster would have benefitted from better collaboration earlier on in the response. Without proper coordination, especially between these two key responding agencies, disjointed aspects of the response were inevitable.

This response lacked multiple degrees of coordination. There was a lack of coordination within the rural organisations affected by the earthquake, and there was also a separate lack of coordination within the official government response mechanism. Additionally, there was a lack of coordination between these two groups, especially as they spanned the local, regional, and national levels. The CDEM agency response arrangement was found to act in parallel with response arrangements of other groups and organisations responding in the same rural space. For example, an informal collective of primary sector groups known as TeamAg (which included industry bodies such as Beef and Lamb New Zealand, rural organisations such as the Rural Support Trusts and Federated Farmers, and MPI representatives) was highly active during the earthquake response, but was not part of the officially planned CDEM response.

All interview participants who worked in responding organisations agreed that a lack of coordination within the rural sector was a large source of frustration and impeded an effective response. The head of a rural organisation involved in the response called the lack of coordination within the sector "our biggest issue." Another participant explains how this poor coordination and communication between organisations was a barrier to effectively doing their work as an emergency manager: "you spend a lot of time and energy telling the same story to 15 different people."

Some coordination amongst the rural sector did exist, which was mostly established during the drought (e.g. the Drought Relief Committee), but this was geared mostly towards farmers and environment-based livelihoods. Since the Kaikōura earthquake, the RAG has been set up for the Canterbury region in hopes of addressing this issue. The RAG is a positive first step in ensuring a coordinated rural sector during the next disaster to the region. However, a risk exists that this group exhibit tendencies to represent businesses and business owners, rather than represent all rural populations, including the most vulnerable who also have the weakest voices. Additional representation in the RAG is currently needed for at-risk rural groups, such as the highly vulnerable elderly, young, unemployed, and seasonal farm workers.

The lack of unified voice in the rural sector contributed to poor coordination amongst rural organisations, and directly inhibited the ability to get a consistent and single source of

messaging from the rural sector to the government response operations. Similarly, the lack of unified voice coming from the official government response towards the various rural populations and organisations was stifled by not having a single point of contact from which all agencies would communicate with rural society.

Those involved in the official response, while acknowledging certain aspects could be improved upon in the future, were content with the overall response. The dissatisfaction of certain organisations and public groups can, in part, be attributed to poor coordination and hence poor communication in both directions.

2.7. Conclusion

The goal of this report is to identify and document the rural impacts experienced in the northern South Island, and especially North Canterbury, following the Kaikōura earthquake. It is in no way a comprehensive review of the response and recovery operations, nor is it intended to point fingers or place blame. Rather this work aims to better understand the consequences and issues caused by a large complex earthquake in a high-income nation, and the human interventions that followed, in the hopes that this will lead to more informed and science-based decision-making to prepare for, respond to, and recover from future rural disasters that will undoubtedly strike New Zealand.

Approximately 10,000 farms and over 10 million farm animals on the South Island are estimated to have felt the shaking from this earthquake (Tables 2.4 and 2.5). However, the ground shaking was arguably not the worst aspect of the earthquake to rural communities and organisations, according to interview participants. Rather, the multi-hazard context was the biggest driver of disaster in this case study. In addition to the ground shaking generated by the earthquake, co-seismic landsliding, landslide dams, the pre-existing drought, and the strained natural environment all contributed to the multi-hazard environment. The seasonal farming cycles, weather forecasts, and financial hardships compounded the effects of the multi-hazard context.

Many interviewed participants found the impacts of the drought much more difficult to deal with as compared to the impacts of the earthquake. The earthquake caused physical damage to many farms and structures (such as paddock fencing), but this was relatively easy for most rural farms and residents to manage. The drought, on the other hand, was a much slower event,

which, over the three years leading up the earthquake, continued to cause financial hardships and wreak havoc on local ecosystems, upon which rural livelihoods rely. The long term damage to farm health, and compromised business continuity, were the most damaging effects of this multi-hazard event in North Canterbury. The few options and drought-coping strategies available to many farms were interrupted when the co-seismic landslides blocked road access in and out of the region. In other words, the earthquake itself was not the largest impact to the rural sector, rather it was the secondary effects and implications of the earthquake that were the most damaging. This underlies an important aspect with regards to rural disasters: immediate physical impacts are usually manageable, but the indirect losses and temporal consequences (such as business continuity) are much tougher to deal with.

This rural perspective on the relative severity of earthquake and drought impacts was not initially well understood by the responding government agencies, who were hindered at the outset of the earthquake by a difficult and inevitably chaotic intelligence gathering operation due to lack of regional access. The lack of integrative coordinating structure able to bring together the entire rural sector and populations with the responding agencies may be to blame. The response priorities identified by local rural residents were not effectively able to be assimilated into the early days of the response. Given the nature of rural livelihoods, specifically the need to accomplish certain daily chores, this rapidly became an issue for rural residents and farms.

The national context in which the Kaikōura earthquake occurred was also a factor in the level of impacts it caused. The relatively strong economic health of rural businesses and the rural sector, as well as the good financial standing of the central government, allowed New Zealand to effectively respond to the earthquake and absorb the financial impacts to the national economy. In this sense, a high-income nation can have advantages in the resources and capacities available to address disaster risk reduction, response, and recovery options not typically available in low-income nations.

Ultimately, the Kaikōura earthquake serves as a reminder of the exposure and vulnerability faced by rural agribusinesses and livelihoods to natural hazards. Addressing the rural impacts of earthquakes will largely depend on understanding the context in which the disaster occurs. As one interview participant aptly summarizes with respect to the agricultural sector, "you're not going to help a farmer unless you understand a farmer, because you need to know what the hell is going on in their mind."

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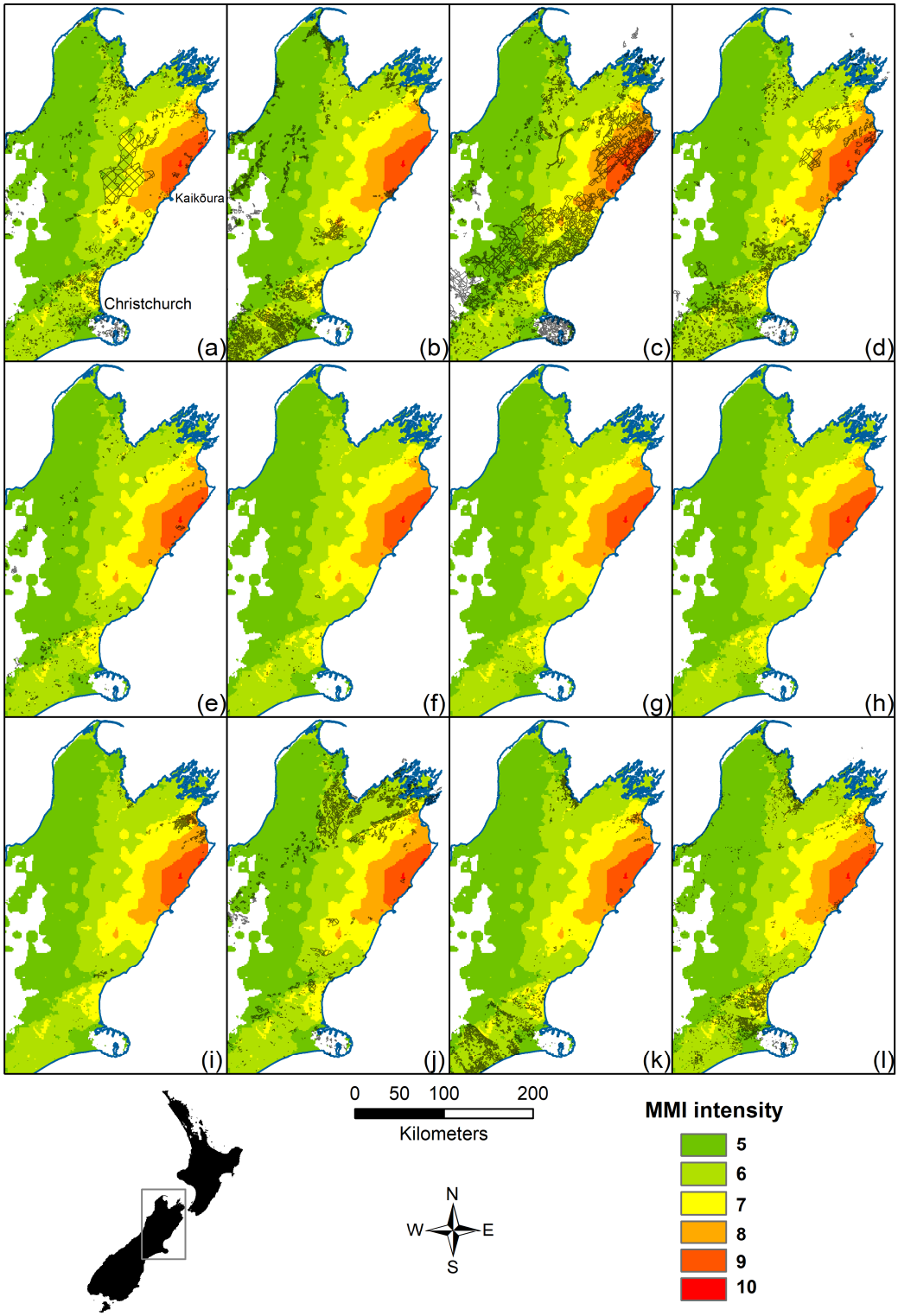
2.10. Appendix



Exposure of property types to Modified Mercalli Intensity (MMI) shaking values during the 2016 Kaikōura earthquake: a) beef farms, b) dairy farms, c) mixed sheep and beef farms, d) sheep farms, e) deer farms, f) pig farms, g) poultry farms, h) all other livestock farm types, i) viticulture farms, j) forestry farms, k) all other horticultural farms, and l) lifestyle blocks.

Chapter Three – 'Rural' needs must drive rural disaster risk management

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Preface

While the previous chapter identified and documented a range of impacts and challenges experienced by rural sectors and communities following a complex disaster sequence in North Canterbury, this chapter seeks to understand *why these may have occurred*. One of the main issues identified in Chapter 2 was a lack of integration of rural needs and priorities into the official government response mechanism following the Kaikōura earthquake. This chapter considers the perspectives of both rural and non-rural actors involved in the earthquake response and recovery to better understand this interface.

Note: some of the background material and interview quotes included in this chapter overlap with material presented in Chapter 2 as this chapter forms the basis of a paper intended to be published separately.

3.1. Abstract

Disaster risk reduction and emergency management systems are attuned to the needs of urban centres. This is due in part to emergency managers' aim of "helping the most amount of people in the least amount of time." Nearly half the world's population however, lives in a rural setting. The contrast between rural and urban risk management is particularly relevant in Aotearoa – New Zealand, a highly urbanised country which is economically dependent on primary industries and tourism in rural, and otherwise remote communities. To better understand how to orient rural disaster risk management, we report on a case study of the response and early recovery to the 14 November 2016 'Kaikōura' earthquake. Interviews, focus group discussion, and document analysis are used to describe perspectives of both rural and non-rural actors involved in the response and recovery. Results show there were difficulties in accounting for rural needs and priorities and limited coordination between actors, during the immediate response. The resulting tension was compounded by a complex legislative environment, and opacity concerning risk management roles and responsibilities before, during, and after the disaster. In order to enhance its effectiveness, we suggest future rural disaster risk management needs to be informed by targeted rural impact assessments to better understand the likely issues faced in rural environments following a disaster.

3.2. Introduction

While rural regions can be diverse and socially complex (Williams and Cutchin, 2002; Terluin, 2003; Johnson, 2006; De Sherbinin et al., 2008), most rural livelihoods globally are based on primary industries and associated service sectors, such as horticulture and raising livestock (Scoones, 1998). This tightly coupled relationship between livelihoods and the natural environment results in a high level of hazard risk in rural areas. These risks continue to grow with cost-effective centralisation of agribusiness processing services and community services (Johnson, 2001; Marin et al., 2015). Long distributed infrastructure networks, for example, expose rural value chains to natural hazards (e.g. earthquake, flooding, and landslides) which can more easily result in isolation and the disruption to social and economic rural systems (Ye and Abe, 2012). Furthermore, the productivity of these resource-based livelihoods (and associated downstream services) are at increasing risk from global climate change, which suggests trends of shifting weather patterns, greater temperature extremes, and warmer overall

seasons (Morton, 2007; UNDRR, 2009; Cardona et al., 2012; IPCC, 2019; Lloyd and Hales, 2019). Reducing losses from disasters, and improving outcomes for rural livelihoods and well-being is a critical challenge for risk management in rural areas.

There is growing literature on the importance of effective governance and decision making to enhance resilience and reduce risk (Adger, 2011; Wood et al., 2015; Wyborn et al., 2017). This is reflected in calls for more inclusive disaster risk governance, as per the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030 (UNDRR 2015). Governance is defined as the processes of decision-making and the processes through which decisions are implemented or not (UNESCAP, 2009). What is required is for governments to "engage with relevant stakeholders (…). There is a need for the public and private sectors and civil society organizations, as well as academia and scientific and research institutions, to work more closely together (…) to integrate disaster risk into their management practices" (UNDRR, 2015, section 7, page 9). The SFDRR calls for communities to be actively involved in disaster risk governance. While there is little mention of the rural context in the SFDRR, it does specifically promote "the mainstreaming of disaster risk assessment, mapping and management into **rural development planning and [land] management"** (UNDRR, 2015, section 30g, page 19, emphasis added). Disaster risk management (DRM) is the practice of reducing the adverse effects of natural hazard impacts to businesses and communities, through the use of risk reduction activities and measures focusing on prevention, mitigation, and preparedness (UNDRR, 2016). Fundamental to DRM is the awareness, identification, understanding, and measurement of disaster risk (UNDRR, 2015).

Disaster risk to rural and urban regions differ, as rural and urban contexts differ. The absence of any rural-specific approaches in the SFDRR reflects a contemporary DRM focus on 'risk to populations,' which drives attention to urban rather than rural disaster risk (Godschalk, 2003; Pelling, 2003; Sheridan and Dolnev, 2003; Vale and Campanella, 2004; Borden et al., 2007; Gosling et al., 2009; Leichenko, 2011; Romero-Lankao et al., 2012). Most DRM practice and policy is also focused on large population centres, meaning that rural risk management knowledge and practice is lacking in comparison (Cutter et al., 2016). Just as disaster risk varies between urban and rural contexts, so too does the manner in which DRM must respectively occur. The wide range of factors and components involved in disaster resilience means that using a one-size-fits-all model to address DRM in both urban and rural settings is unlikely to be effectual (Cutter et al., 2016), and new approaches may be needed.

The purpose of this paper is to investigate rural DRM practices in a post-disaster situation. In doing this, we provide insight into the different perspectives of rural and urban actors who took part in the emergency response and early recovery. Identifying commonalities and points of difference helps clarify particular aspects of DRM that need to be more sensitive to rural needs and priorities, and why. A New Zealand case study is used to achieve this, with a focus on the rural North Canterbury region, South Island, in the first year after the 2016 'Kaikōura' earthquake. The sections that follow frame this analysis beginning with an outline of the governance structures and geographical constraints influencing the response and recovery, and the methodology used to gather and analyse the data. Conclusions point to possible uses of this work at the local, national, and global levels.

3.3. Case study context and background

3.3.1. New Zealand setting

New Zealand is a small, developed island nation in the South Pacific, exposed to a wide range of natural hazards (MCDEM, 2007). Situated on a dynamic plate boundary between the Pacific and Indo-Australian tectonic plates, it is seismically active, has a number of active volcanos, is exposed to far- and near-field tsunami hazards, and steep terrain throughout the country create landslides hazards. New Zealand's latitude means that the country sits in the path of the 'roaring forties' trade winds, where it is exposed to the convergence of Antarctic and tropical weather patterns creating flooding and storm hazards throughout the country (MCDEM, 2007). New Zealand is the second riskiest country in the world in terms of expected losses from natural hazards (Lloyd's of London, 2018). This high exposure is evidenced in the nationally noteworthy disasters that have affected rural communities in particular within the past fifteen years, such as flooding in the Manawatu district (Smith et al., 2011); droughts in the Canterbury region (ECan, 2016); and snowstorms in the Otago, Southland, and South Canterbury regions (Kelly and Smith, 2012). Six years prior to the 2016 Kaikōura earthquake, central Canterbury's rural regions were also impacted by the 2010-2011 Canterbury Earthquake Sequence, allowing for opportunities to better understand the impacts of rural earthquakes in Canterbury (Whitman et al., 2013; Almond et al. 2010), although a deadly and highly damaging

aftershock shifted much of the research attention to a nearby urban centre (Potter et al., 2015). Spector et al. (2019) synthesise the full range of studies that have focused on rural disasters and rural resilience in New Zealand.

New Zealand's strong reliance on the primary industries (New Zealand Treasury, 2017) is not commonly characteristic of a developed economy (Kamber et al., 2013). The primary sector (which consists of livestock farming, horticulture, forestry, fisheries and associated services) accounted for 7.5% of national gross domestic product (GDP) in 2015, and made up over 50% of New Zealand's total export earnings for that same year (New Zealand Treasury, 2016). Flow-on effects from the primary sector (such as processing, manufacturing, and rural transport businesses) also contribute heavily to GDP (MCDEM, 2007). Tourism is another major contributor to the New Zealand economy, accounting for 5.8% of GDP (Statistics New Zealand, 2020), and relies on the natural environment, picturesque scenery, and a range of outdoor activities that primarily occur in rural areas.

Multiple social factors in New Zealand contribute positively to rural disaster resilience, such as a modern form of government, low levels of perceived corruption, below average levels of poverty, a good education system, strong social welfare and health care systems, high levels of insurance coverage, and a robust building code (Buckett, 2014; Fleming et al., 2018; LGNZ, 2019; Lloyd's of London, 2018; OECD, 2019; OECD, 2020). These factors suggest there is relatively high disaster recovery capacity with comparatively high public and private resourcing available, strong public and private institutions, and a relatively resilient built environment (Hewitt, 1983; Dowrick et al., 2003).

Additionally, New Zealand has strong national DRM legislation (IFRC, 2014), though responsibilities are spread across multiple pieces of legislation (NEMA, 2020a). Since 2002, DRM is governed primarily by the Civil Defence and Emergency Management (CDEM) Act 2002, which sets out a national framework for disaster risk reduction, readiness, response, and recovery at all levels (New Zealand Legislation, 2019). The CDEM agency is the government lead agency for disaster responses to natural hazards (such as earthquakes) in New Zealand. The CDEM framework uses a hierarchical arrangement designed to foster the common principles, structures, functions, processes, and terminology required for effective interagency coordination of the government response (NEMA, 2020b). The CDEM Act 2002 does not, however, distinguish between disaster responses to the rural and urban contexts (New Zealand

Legislation, 2019). Other legislation that guides strategies, plans, policies, codes, and practices supporting DRM are spread across the following acts (NEMA, 2020a; NEMA, 2020c):

- Biosecurity Act 1993
- Building Act 2004 and Building Code
- Defence Act 1990
- Earthquake Commission Act 1993
- Epidemic Preparedness Act 2006
- Fire and Emergency New Zealand Act 2017
- Greater Christchurch Regeneration Act 2016
- Hazardous Substances and New Organisms Act 1996
- Health Act 1956
- Health and Safety at Work Act 2015
- International Terrorism Act 1987
- Local Government Act 2002
- Maritime Transport Act 1994
- Public Works Act 1981
- Resource Management Act 1991
- Soil Conservation and Rivers Control Act 1941

While not every Act applies to the rural context, this decentralization of DRM roles and responsibilities can contribute to a complex national policy setting.

Furthermore, there are multiple public, private, and government and non-government actors that are actively involved in rural disaster response activities in both official and unofficial capacities. These include strong sector based organizations and industry groups (e.g. DairyNZ and Beef and Lamb New Zealand), large agribusinesses (e.g. Fonterra), rural-based organisations (e.g. Federated Farmers and the Rural Support Trusts), and the Ministry for Primary Industries.

3.3.2. The 14 November 2016 Mw 7.8 'Kaikōura' earthquake

On 14 November 2016, multiple fault lines ruptured to produce a moment magnitude (Mw) 7.8 earthquake, causing widespread damage and impacts throughout the northern South Island and the capital city Wellington, on the southern coast of the North Island (GeoNet, 2016).

The epicentre was located 5 kilometres from the rural town of Waiau (15 kilometres north-east of Culverden) in New Zealand's South Island (GeoNet, 2016) (Figure 3.1). While ground shaking was felt across the northern South Island and southern North Island, the most strongly affected areas were North Canterbury (the Kaikōura and Hurunui Districts) and Marlborough District (NEMA, 2020d). In the North Canterbury regions, nearly 2 minutes of "extreme" ground shaking resulted in up to twelve meters of horizontal and vertical ground displacement (GeoNet, 2016). The shaking intensity resulted in regional co-seismic hazards that included landslides, liquefaction, and tsunami, mostly affecting rural areas (Dellow et al., 2017). There was considerable damage to land, buildings, critical infrastructure (such as roads, power and telecommunications), agricultural equipment, and farm infrastructure including livestock water supplies, tracks, and fences. Many farming communities (as well as the township of Kaikōura) were isolated from regional hubs due to widespread disruption of the land transportation network (Davies et al. 2017; Cradock-Henry et al., 2018; Trotter and Ivory, 2019).

Importantly, this earthquake occurred in a region affected by, and still actively dealing with, the impacts of a prior three year drought (Hurunui District Council, 2017; Stevenson et al., 2017; Wilson and Simmons, 2018). On 22 February 2015, MPI classified this Eastern South Island Drought as a 'medium scale adverse event,' triggering much needed recovery measures and funds aimed at helping farmers and rural communities (MPI, 2017). The Hurunui District Council would release an update on the drought conditions, on 24 December 2015, which stated "the majority of the District has received less than 50% of average rainfall over the last 18 months. The severity of the drought is random across the district with localised areas more serious than others" (Hurunui District Council, 2015). The 'medium scale adverse event' declaration for the drought by MPI ended on 31 December 2016, nearly 7 weeks after the Kaikōura earthquake. The earthquake therefore compounded the psycho-social and economic drought stresses being experienced by many rural populations (Stevenson et al., 2017).

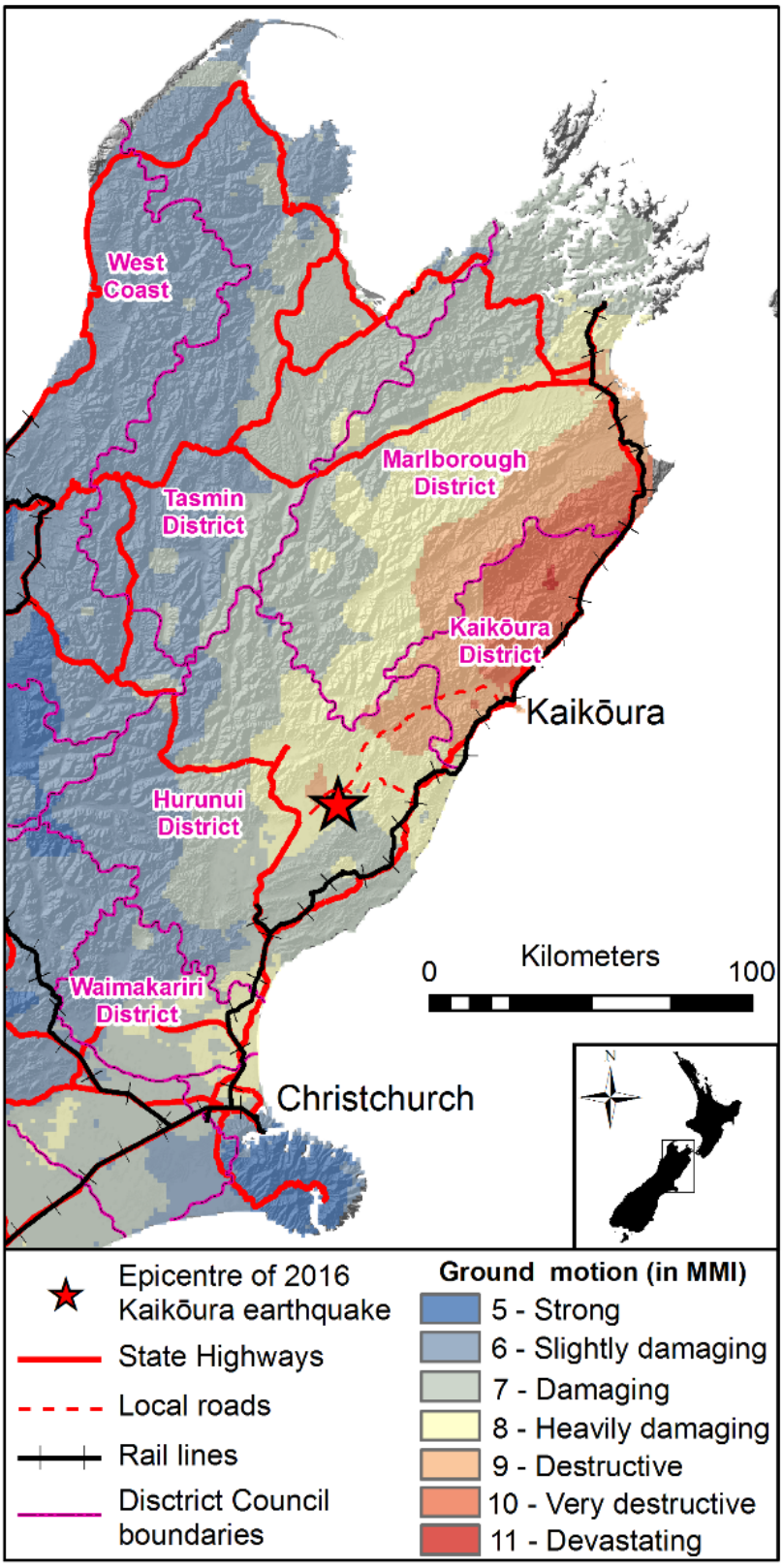

Figure 3.1 Exposure of road and rail transportation networks in the Hurunui, Kaikōura, and Marlborough Districts with respect to strength of ground motion (on the Modified Mercalli Intensity scale) from the 2016 Kaikōura earthquake. Ground motion data from Bradley et al. (2017).

3.3.3. Response to the Kaikōura earthquake and rural DRM in New Zealand

When the earthquake occurred just after midnight, over 10,000 rural properties and 10 million head of livestock on the northern South Island were subject to 'strong' or higher levels of ground shaking (measuring 5 and above on the Modified Mercalli Intensity scale) (see Chapter 2). Moderate to strong ground shaking, liquefaction, and some minor structural damage to buildings did also occur in the cities of Wellington and Christchurch, which complicated and increased the scale of the event and necessary response (Stevenson et al., 2017; MCDEM, 2017b).

Co-seismic landslides disrupted the main transportation artery up the coast, State Highway 1, as well as the only other access road into the Kaikōura District, State Highway 70 (also known as the Inland Road). This immediately isolated the town of Kaikōura, and other communities that relied exclusively on these roads (Davies et al., 2017). Across the impacted regions, local ad-hoc and informal responses were activated (Stevenson et al., 2017), including by a number of rural organisations already working on drought relief in the region, such as the Rural Support Trust and Federated Farmers. At 10:15am on 14 November, the Kaikōura District Council declared a local state of emergency, with Hurunui District Council following suit at 11:56am (see timeline in Figure 3.2). On the same day, the central government passed the Hurunui – Kaikōura Earthquake Recovery Bill to better enable resourcing for the recovery of the region, and the government brought forward the CDEM Amendment Act 2016 that was already in process of being finalised.

The CDEM framework requires appropriately trained CDEM personnel activate from within their business-as-usual roles in district, regional, and national government agencies, as well as the private organisations who also have a mandate under the CDEM Act 2002 such as critical infrastructure organisations, to respond to natural hazards. In Kaikōura and Hurunui, local councils are very small, making it difficult for them to staff ongoing response to a disaster of this scale unaided (NEMA, 2020d). On 15 November, the first wave of CDEM support personnel were helicoptered into the Kaikōura township to support and coordinate the CDEM response in both districts (Mackie, 2017).

Access in and out of the earthquake impacted areas remained a major issue for the response due to lack of road access (Davies et al., 2017). Helicopters and boats were required to transport personnel and resources into the township, and tourists out. At this point, responsibility for managing road closures in both the Kaikōura and Hurunui Districts fell to

CDEM. It was not until 18 November that the first New Zealand Defence Force convoy of all-terrain vehicles was able to traverse the damaged Inland Road to access the town of Kaikōura by land. On 20 November, temporary flights to the Kaikōura airport resumed.

It was not until 29 November 2016, that the CDEM Amendment Bill 2016 was enacted, followed on 5 December 2016 by the Hurunui / Kaikōura Earthquake Recovery Emergency Relief Bill. On the same day, the government committed to repairing State Highway 1 and the railway along the coast, removing some of the uncertainty around the major transportation infrastructure, and thus access, for these districts. On 9 December 2016, a National Period of Transition began, which preserved some of the legislative decision-making powers deemed necessary for the regional recovery. Access along State Highway 1 between Christchurch and the Kaikōura township was partially restored on 21 December 2016, allowing for travel during daylight hours. However, the continued closure of State Highway 1 north of the Kaikōura township and extensive damage to minor local roads meant that many rural communities and residents across the region continued to struggle with access issues for over a year. The National Period of Transition did not end until 10 June 2017, at which point only the Kaikōura District Council declared a local period of transition, providing a further 30 days of recovery decision-making powers at the district level.

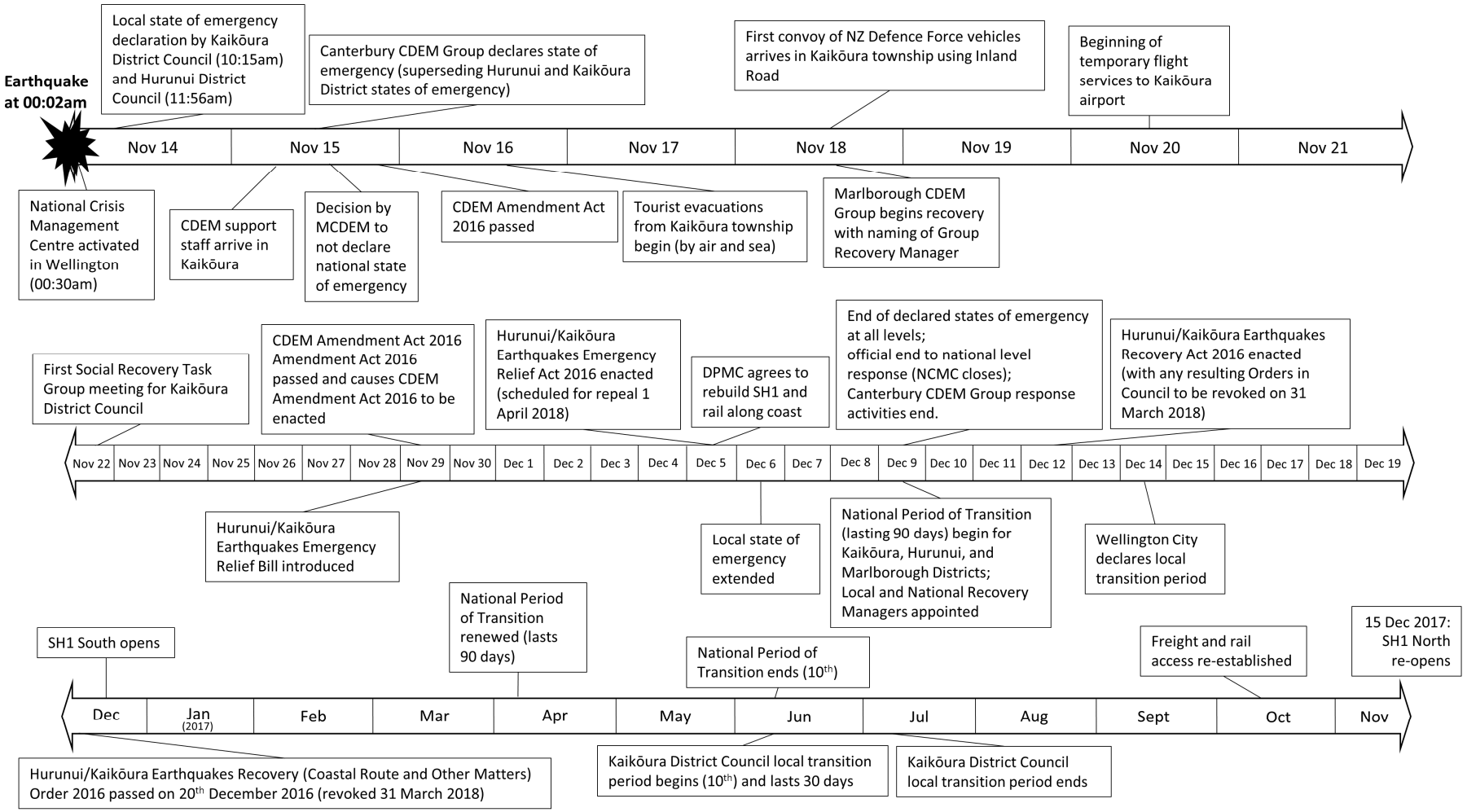

Figure 3.2 Timeline of major response, recovery, and legislative events in the 12 months following the 2016 Kaikōura earthquake.

While CDEM (as well as local and regional government councils) have the legislative power to declare states of emergency across New Zealand, when events impact rural areas, and especially the primary industries, they may also fall under the classification of 'adverse events' by a separate declaration mechanism belonging to MPI. Following extreme climatic events, biosecurity incursions, and other natural hazards that impact farms, MPI is mandated to guide government decisions on recovery assistance under the Primary Sector Recovery Policy (MPI, 2016), as the agency responsible for day-to-day oversight, management, and regulation of farming, fishing, food, animal welfare, biosecurity, and forestry sectors in New Zealand. The respective classification of the Kaikōura earthquake as a disaster under the CDEM Act (2002) and as an adverse event under the MPI Primary Sector Recovery Policy, however, does not align simply or explicitly since it is based on different underlying criteria.

Operations and logistics for the Kaikōura earthquake response was led by the respective CDEM Groups in each affected region, as per the CDEM Act (2002). While a state of emergency was not declared nationally, a regional state of emergency was declared in Canterbury. Therefore the Canterbury CDEM Group coordinated regional disaster response and recovery operations across the Kaikōura and Hurunui Districts (Figure 3.3). Major response and recovery activities were undertaken in the Marlborough, Nelson-Tasman, and Wellington jurisdictions by their respective CDEM Groups, although states of emergency were not declared in these regions (MCDEM, 2017b). As this earthquake affected multiple regions, response activities were supported and coordinated at the national level from within the capital's National Crisis Management Centre (NCMC).

A case study analysis of the response and recovery to the 2016 Kaikōura earthquake allows for an examination on the roles and responsibilities of the organisations involved, at all levels, and provides insight into disaster response and DRM in the rural context.

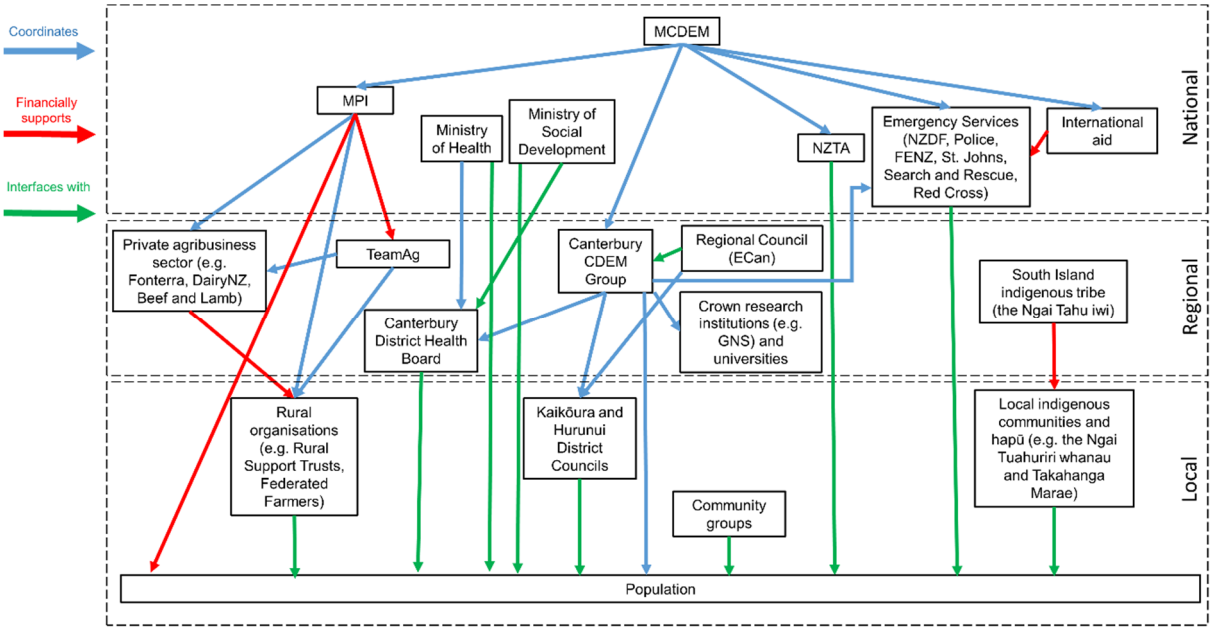

Figure 3.3 Organisations and response arrangements at play in North Canterbury following the 2016 Kaikōura earthquake.

3.4. Methodology

Purposeful sampling was used to select interview participants (n = 18) on the basis of their involvement in rural DRM in general, and the Kaikōura earthquake in particular. Interviews were semi-structured, lasting between 45 and 75 minutes. Ten interviews were face-to-face and eight were phone interviews, due to logistical constraints.

Data was collected between September 2017 and August 2018. Participants included full and part-time emergency managers and disaster risk managers from government and non-government organisations, from both policy and practice domains active at local, regional, and national levels (Table 3.1). Thirteen participants were full-time professional emergency managers, four participants worked for branches of government other than CDEM, and three were from non-governmental organisations. Five senior personnel from other regional CDEM Groups were interviewed as subject matter experts, but were not directly involved in the Kaikōura earthquake response. All other interviewees were active in the response, and provided their perspectives on that basis. A small focus group was conducted with senior level emergency managers (n = 4), each of whom had also participated in an interview.

Open-ended questions were designed to understand the perspectives of both rural and non-rural actors involved in the earthquake response and recovery, as a way to explore this

interface and comment on the integration of rural needs and priorities into the official government response mechanism following the Kaikōura earthquake. Interviews were mostly face-to-face, but also over the phone when necessary.

Table 3.1 Professional distribution of interview participants and level at which they normally operate.

	Operational responsibility		
Organisation	Local	Regional	National
CDEM	-	9	-
Local government	4	-	-
Other central government agencies	-	1	2
Non-governmental organisations (NGOs)	1	1	1

Participants were initially identified by role, and subsequently through the process of "snowballing" as interviews proceeded, as described by Patton (2002). The interview process ended when adequate representation across levels and professional experiences was considered to have occurred, and information saturation reached, as identified by this study's authors. Ethical review and approval was obtained from the University of Canterbury's Human Ethics Committee (reference number: HEC 2017/34/LR-PS).

Transcribed data was manually and iteratively coded using inductive framework analysis (Thomas, 2006). Themes related to rural vulnerability, organisational interfacing, and response coordination were first identified by the lead author, then discussed by all authors. Transcription and analysis was supplemented with additional insights obtained from peer-reviewed academic journals and 'grey' literature (such as government reports, policy documents, and emergency management newsletters).

3.5. Findings

The 2016 Kaikōura earthquake provides an illustrative example of divergent priorities exhibited by responding organisations following a disaster. This divergence is due in part to an imprecise policy setting to the extent that the CDEM Act 2002 does not distinguish between disaster responses in rural and urban contexts, nor does it adequately account for the role of MPI as an important day-to-day actor in rural regions. While many rural organisations were highly active in the earthquake response (many financially supported by MPI), the interface between CDEM and MPI is a useful analogy for considering the different response perspectives

between rural and non-rural actors. While MPI is present in rural regions before, during, and after disasters, CDEM is an urban-based agency who is not consistently present in rural regions. Results show the extent to which legislation and policy environments dictated management activities by these two major responding agencies, to two interacting disasters: CDEM led the Kaikōura earthquake response efforts, but was not involved in the multi-year response to a pre-existing regional drought, which was the responsibility of MPI. The presence of two different government agencies concurrently responding to two overlapping events complicated one another's roles and responsibilities. The net result was limited alignment between immediate priorities and coordination issues between these two agencies during the response to two very different hazards within the same disaster.

3.5.1. Two responding agencies

Following the earthquake, there were a number of local and regional actors, as well as those from national response agencies, attending to disaster response and recovery needs in North Canterbury. Findings indicate the complexity of the response may be due, in part, to the number of actors involved, and the fact many of these individuals and organisations had not worked closely together before. As the lead agency mandated to coordinate disaster responses across New Zealand, CDEM most often coordinates across those government agencies representing infrastructure, transportation, health and social development. Because not all disasters occur in rural areas, and therefore MPI does not necessarily always have a disaster response role, CDEM and MPI had little experience working together. However, because the Kaikōura earthquake was classified as an adverse event under MPI's Primary Sector Recovery Policy, it was also required to support rural response and recovery actors.

Both CDEM and MPI played important roles during the response, however both agencies focused in different directions, accessing very different networks of actors. With responsibility for the primary industries, MPI is required to be active and well connected in the rural sector, and staff have long-standing relationships with rural financial services providers, private industry and agribusiness, advocacy, and rural support groups. By contrast, CDEM is required to establish and maintain strong connections with emergency services, lifeline infrastructure providers, and local government.

The Kaikōura earthquake response revealed that this arrangement had in effect created parallel response operations: one championed by rural organisations with an explicit focus on rural perspectives, and the other necessarily reliant on its hierarchical framework. Although the legislation provides for distinct roles for MPI and CDEM in DRM, and gives CDEM responsibility for coordinating earthquake response, CDEM is poorly placed to do so in rural areas where it lacks existing networks and relationships. By contrast, MPI is regularly active and well connected in the rural sector but is not well connected to CDEM. While national legislation provides a basis for joint response operation, it does not account for divergent response drivers nor does it provide mechanisms for coordination between CDEM and MPI during and after disasters in rural areas.

Involvement by MPI in the earthquake response and recovery outside of the CDEM framework included funding support for rural organisations, funding support directly available to farmers, access to consultants and rural recovery specialists, and the coordination of a skilled farm worker placement programme to help with on-farm repairs (MPI, 2017). These support measures to the North Canterbury and Marlborough Districts were valued at $13.32 million NZD (approximately $8 million USD) (MPI, 2017).

3.5.2. Two disasters

Results show that North Canterbury experienced overlapping and in some cases compounding effects due to the Kaikōura earthquake and an on-going multi-year drought. Earthquake impacts to the region were considerable (see Chapter 2), prompted national and international media attention, and resulted in the declaration of states of emergency in multiple districts. It has been established that while this kind of focusing effect is common after earthquakes, it is less likely to be generated by less visually dramatic and slow-onset disasters such as droughts (Birkland, 1998). This is consistent with the differing rural and non-rural perceptions of the relative impacts of the Kaikōura earthquake compared with the drought that preceded it. Results of interviews and focus group showed that the effects of the on-going three year drought "had a far bigger impact [on rural regions] than the earthquake" for many rural communities. One of the main reasons for this is the sensitivity of primary industries to even slight variations in the natural environment (Kurukulasuriya and Rosenthal, 2003), coupled with the nature of farming businesses to operate and rely on seasonal cycles. As a result, the

effects of a drought can persist long after the drought itself. A rural organisation interviewee explains:

> Put it this way, [the drought] is over in terms of moisture deficit. The ground is full of water, we've had a very wet winter. But the financial effects will go on for three or four years.

These negative flow-on consequences to agribusinesses caused by the drought are difficult to quantify, but include the compounding effects of animal welfare issues on the health of the entire farm system over time. Earthquake impacts were found to most strongly affect rural regions in how they worsened the effects of the drought to the region (see Chapter 2). An interview participant summarises: "you lose a cow, you lose a calf, you lose a ewe, it's a production over time that you lose."

In response to the drought, MPI was active in the North Canterbury region to support local and rural based organisations. These efforts increased the social connectivity and social capital of the region by using 'farm strategy field days' and social gatherings, to build resilience not only to drought. According to interviews, these field days allowed farmers to share lessons on coping with the drought, to learn about management strategies, to empathise, and to boost morale. This allowed rural population involved in the primary industries to build drought resilience; a participant comments: "as the drought went on farmers actually got better at handling it because they learnt from experience how to handle it and they learnt to take action sooner."

An unintended consequence of these drought field days was that this social capital would also be effective in increasing earthquake resilience. Since drought is not classified as a disaster, but rather an adverse event, CDEM is not involved in responses to drought, and was not involved in MPI's efforts prior to the earthquake. However, in the days following the earthquake, CDEM's disaster response operations in rural areas relied extensively on the drought response arrangements established by MPI and other rural organisations. An interview participant explains the benefits of drought resilience efforts for the earthquake response:

> So that's the main thrust of the drought was having a committee, having weekly conference calls and having all the rural organisations involved including banks and accountants, stock firms, vets, Rural Support, the local council, Beef and Lamb, Dairy NZ, all those organisations. So, moving onto the earthquake, it was a huge help that we had a committee there. When the earthquake struck we had a conference every day. So we changed from being

> the Drought Committee to the Earthquake Committee. (…) We pulled a few more people in, and that was a huge help in organising those first few days.

3.5.3. Asymmetrical priorities

The CDEM response to disasters is required by legislative mandate to prioritise human safety and the preservation of property. This implicitly dictates a focus on population centres and the need to provide adequate water and food supplies to those affected by the disaster. This priority to focus response efforts on more densely populated centres was acknowledged by interview participants:

> What was happening was – and it was perfectly reasonable – but the focus [of the response] was on the townships. And in some cases, nobody had ever checked the outlying farms to see that they were okay or nobody had information to know that they were okay.

As the early days of the official government response was mostly directed towards Kaikōura township and stranded tourists, some remote areas and rural communities were isolated for longer periods of time compared to townships such as Kaikōura. Many farmers and rural residents were forced to deal with the immediate impacts of the earthquake on their own. In terms of human welfare and risk to life, rural farms and communities did not see the provision of food, water, and shelter as priorities. As a long time rural resident put it: "country people have always got stuff in the freezer, they're not going to starve. So, actually, in some ways food to country people is probably not a priority." This reflects international trends that rural regions are typically more self-reliant than their urban counterparts (Bruneau et al., 2003; Waugh, 2013).

The perspective of one rural interview participant after the rural earthquake was that "people are fine, cows aren't." Risks to livestock posed long-term effects on production, with direct implications for the viability of some local businesses as well as for community wellbeing. Isolated agribusinesses were not able to move product off of farms to access markets (such as delivering milk to a centralised processing plant), nor move product onto their farms to address immediate livestock welfare needs. Animal welfare value chains were disrupted, leading to long term economic challenges for many. As one North Canterbury resident explained:

> [Poor animal welfare] can have catastrophic consequences for that farmer (…). Every calf, and their ability to milk next year, or [for the next] five years, has gone. So it's not just the consequences now, it's the long term consequences and people don't understand that.

The seasonal nature of agribusiness added an additional layer of complexity to the Kaikōura earthquake impacts. Disruptions at critical points in the farm cycle (such as sowing, harvesting, or lambing seasons), had the potential to impair an entire season of farm production; as one rural NGO representative noted: "if you don't get those things done within the right seasonal window that actually throws the farm out for a whole 12 months." Stevenson et al. (2017) reported that the earthquake occurred three weeks into cow mating seasons, which has important implications for the productivity of livestock farms in the following years. Meeting key seasonal milestones in livestock and crop growing cycles can therefore have long term implications to farm health and was considered a priority for many farms.

Moreover, natural resources (such as food and water for livestock and crops) as well as financial resources (such as savings and credit with banks) had already been stretched thin by the effects of the drought. Many farmers were already struggling to ensure animal welfare needs were being met. Common strategies used for coping with drought, such as selling off stock temporarily or delivering food and water to stock, were no longer possible due to disruption to the transportation network. For these reasons, farmer access to roads and transportation infrastructure was essential to address immediate livestock welfare needs.

A section of the Inland Road in North Canterbury therefore became a contentious aspect of the earthquake response, as it directly pitted the rural priority to address livestock welfare needs against the CDEM mandate to prioritise human health. A section of this road was cordoned off and designated impassable due to the risk of further co-seismic rock fall and land sliding. As the lead agency, the responsibility of managing this road fell to CDEM:

> If we were in the ideal world (…) we [CDEM] would not have been doing that at the level that we were. We were managing [the inland road cordon] rather than supporting it. Ideally (…) we would have supported Hurunui [District] Council and Kaikōura [District] Council to have run that road, or the [New Zealand Transport Agency] to run that road, but it became pretty apparent that no one was going to… They had enough troubles of their own.

While CDEM was required to prioritise the safety of those attempting to transit through cordoned roads, rural residents found the road closure measures excessive, especially for some rural actors who were more accustomed to off-road travel (Cradock-Henry et al., 2018;

Cradock-Henry et al., 2019). As a result, road management of the Inland Road became an important issue for rural residents, communities, and agribusinesses, and exemplifies the misaligned priorities between CDEM and rural perspectives.

3.5.4. Coordination issues

Finally, the results of the analysis show the misalignment between the CDEM legislative mandate and rural priorities was exacerbated by lack of provision for coordination between CDEM and MPI roles and responsibilities following a disaster. This meant that fundamental differences in legislative mandates between these agencies were difficult to address. CDEM may act within rural regions following a disaster according to the CDEM Act 2002 (New Zealand Legislation, 2020). By contrast MPI is required to operate in and focus on rural regions before, during, and after any event, including damaging earthquakes. However, neither of these legislative mandates provides for coordination with the other, and the perspectives and institutional cultures of each agency are very different.

From CDEM's perspective, the intensive hands-on MPI approach to resident support appeared at times to be ad-hoc. Commenting on engagement around access to road cordons, for example, an interviewee noted:

> We ended up with an MPI representative [in the EOC] who came and went, but particularly in regards to that Inland Road, [he] would raise issues with us about farmers who wanted access, and so he would say this farmer needs access to do this job, or this farmer needs this plumber to get access so that they can fix the irrigation, or whatever it might be, but just to have a contractor turn up at a checkpoint saying 'I'm going to that farm,' they're not going to get through. We need to be able to find out what they're doing and give them permission. They can't just expect to roll through.

In the absence of a clear and transparent coordinating platform, the operational environment became highly complex, increasing ambiguity around roles and responsibilities. Emergency managers with CDEM were well aware of the networks MPI had created in North Canterbury during the drought, with one CDEM interviewee acknowledging "the social structures that were in North Canterbury [before the earthquake] probably were about as strong as they possibly could be." Because of these existing networks, CDEM assumed MPI would be the conduit through which rural issues might be proactively collected and transmitted to them, with one interviewee explaining:

> The rural sector is (…) complex. (…) There are structures that sit in behind it that actually we could be drawing on a lot more, and that's that real business side of the rural sector that sits along people who are just living rurally, and we haven't really explored that before, up until the quakes. And I don't think we really understood that. We also thought that's where MPI sits and (…) we kind of assumed that MPI would act as a conduit and our advocate for that part, you know that dimension of the rural sector.

Conversely, MPI's approach views leadership and coordination of the rural sector as the responsibility of affected communities themselves. Results showed that although MPI recognizes that leadership and coordination roles are important, they do not view themselves as being in a position to assume these roles. One interviewee explained:

> We're happy to support, but MPI's philosophy is that [rural sector coordination] is best led by the [rural] people involved. We provide the secretarial support, we're on all the calls, we take messages back and forth and answer questions and things like that. It's best when it's their committee, not ours.

In addition to issues with coordinating and aligning response priorities between CDEM and MPI, these agencies appeared to have very different world views and perspectives on leadership and coordination. While this study did not explicitly explore difference in workplace culture between the two agencies, it is possible that this may have hampered the coordination of rural disaster response efforts (Huntington, 1993). A CDEM interviewee elaborated:

> We are two sectors with two very different expectations about what will happen, two very different ways of working, and two sets of languages that are enough the same but enough different that it really causes confusion when we talk to each other, so recovery for us means something different from recovery for MPI, and that makes it really, really difficult.

One of the ways in which increased coordination between MPI and CDEM could enhance rural disaster response and recovery is by sharing perspectives in order to foster a mutual understanding of legislative mandates. As mentioned earlier, animal welfare issues were an important rural response priority after the earthquake. However, the CDEM Act 2002 does not reference animal welfare directly, and it is not clear whether the CDEM mandate to "save lives and property and to help communities begin to recover" (section 112(1), MCDEM, 2015b) includes livestock and crops. As a result, CDEM personnel focused on human safety and wellbeing can easily overlook the importance of livestock welfare, and the role of healthy agribusiness, to rural populations and in helping farm-based communities recover.

Similarly, the operational ramifications of resource availability with respect to local government in rural versus urban areas was unclear. The Kaikōura earthquake response, for example, did not have the agency representation usually available to those coordinating an urban earthquake response. A rural emergency manager explained that "it's a little bit hard for us because a lot of the agencies that you get in town aren't represented out here."

This tension was further complicated by the fact that rural areas are not just comprised of farms and agribusinesses, but also of demographically varied communities (Wilson and Simmons, 2018). The disaster response needs of these populations (such as the elderly, disabled, or youth) can be very different from the disaster response needs of farmers:

> In terms of resilience, there's a huge difference between farmers and how they handle a disaster, and township people (…). [Some of whom have] no networks, (…) no money, they're not assertive, whereas the farmers they can look after themselves to a certain extent. It's huge the difference there.

The diverse populations and demographics of these rural communities posed additional challenges for the wider rural sector to interface with the official government response to the earthquake. A clear and transparent coordination mechanism acknowledging where the unique disaster response needs of rural regions could have been communicated would have helped facilitate the collective response effort.

A coordinative mechanism of this kind would also have helped the wider coordination of rural regions themselves. This challenge is explained by an interviewee:

> One of the biggest headaches we had was people like stock agents and fertilizer companies and things, they go and check on their clients but they wouldn't check on the other person next door, they'd just go and see their clients. So you'd have roads in places where three people had been visited and three people hadn't. So you are trying to do a whole sweep to make sure people are alright and for some poor buggers you were the sixth person up the drive (…) and they were getting pretty sick of people. But then you go to the next person and they hadn't seen a soul.

The sheer number and diversity of organisations operating independently but side-by-side within the rural sector, each with their own goals and internal command structure, made initial risk assessment difficult, and continued to fragment the sources and types of information available for those attempting to coordinate the response. Again, the absence of institutional alignment likely contributed to a variety of different disaster response management style between the hierarchical CDEM structure and the diverse local response activity (Huntington, 1993). A CDEM interviewee explains:

> When the community spontaneously organises [to respond to an event] we're not able to capture that because we're too structured and rigid to be able to morph, and so [people become annoyed]. Basically, what we needed is some way of capturing what they were doing, and pulling it into our process, amalgamating it with our process.

It has been well established that cross-sector coordinating mechanisms are essential after disasters (Smith and Birkland, 2012; Beaven et al., 2016) to allow for collective response and recovery efforts. As a regional emergency manager puts it, "we can't form a relationship with all these different forms of rural people, (…) so we need a mechanism that brings them together, so that we can have that relationship." To be effective in the rural sector, such a mechanism would need to coordinate not only local actors, but also the two largest government agencies with rural disaster response responsibilities, MPI and CDEM.

3.6. Discussion

Results of the analysis show the presence of a tension between rural and non-rural actors during the earthquake response. In this section, we consider some of the implications of this tension, the role of divergent response priorities, and the consequences of a lack of clear transparent coordination mechanisms to align the range of actors and mandates involved in rural disaster response in New Zealand.

Looking more broadly at the socio-historical context of this disaster response, it is clear that rural populations in North Canterbury were already stressed by financial and other stressors created by the preceding three years of drought. In addition, rural communities across New Zealand are currently undergoing considerable demographic, technological, and social change, due to centralisation of services, a rural-to-urban drift for employment purposes, and growing populations of retirees and lifestyle block residents (Smith et al., 2011; Cameron, 2017; Jackson and Brabyn, 2017). Current legislation provides for MPI support for rural-based primary industries on the one hand, while on the other requiring CDEM to coordinate earthquake disaster response and recovery within these same regions. Neither of these agencies is currently well placed to meet the evolving needs of changing rural communities in the face of disasters.

Since the CDEM Act 2002 does not clearly distinguish between urban and rural response and recovery operations, and is mandated to prioritise life risk and safety, it is in effect implicitly focused on larger population centres. Response priorities or urban centres do not

necessarily align with those of rural regions. For example, CDEM is required to ensure that residents have access to adequate food, water, and shelter after disasters. In urban areas, where water is supplied through reticulated systems, and residents typically buy food on an as-needed basis from supermarkets, this focus is both appropriate and necessary. However, the remote nature of many rural households means that grocery supplies are often bought and stored in bulk, and that water is often available in and around farms in the form of wells or rivers. While these water sources may not be sufficient or suitable for irrigation or livestock purposes, rural households often have water readily available. Shelter is also readily available in many rural areas given existing farm structures, or attainable through the use of tools and farm machinery on hand.

As many farmers and farm workers often live in the same location as their place of work, the farm and the household are often one and the same. Business health is therefore often intimately related to household health, as if one fails the other usually faces similar circumstances (Phillipson et al., 2004). The post-disaster needs for this context are different than, for example, urban residents who may be a salary or wage based workers and whose homes and workplaces are often physically separated. For many rural communities and the farming sector, it is not access to food and water that is the priority (though sometimes this can be needed), but business continuity and rural livelihoods. This is similar to post-disaster priorities recognised in many urban settings (Sahebjamnia et al., 2015), however urban business do not often require uninterrupted daily tasks related to livestock welfare, irrigation requirements, and the ability to move perishable product to the market in a timely manner (Rosenzweig and Parry, 1994). Livestock welfare in particular is often an urgent concern following a disaster, since it is time sensitive and losing stock is an emotive as well as financial issue. This underlies an important aspect with regards to rural disasters: spatial impacts are usually manageable, but the temporal impacts are much more difficult to deal with.

These different views on response priorities may stem from a different tolerance for specific types of risk in rural versus urban regions. Take 'risk to productivity' for example. While many urban professionals and company employees are able to walk away from their work temporarily, the nature of rural livelihoods relies on consistency and regularity, regardless of natural hazards. The nature of farming business implies that any disruptions now will have negative impacts to long-term farm health and viability in the future. The risk to agribusiness production was considered the most important issue to all the farmers and rural organisations

interviewed as part of this study. Agribusiness continuity problems experienced after the earthquake will have negative long term financial impacts and increase future disaster risk. Rural businesses struggling to operate after unfavourable conditions caused by a natural hazard are not well placed financially to survive the burden of a future hazard (Whitman et al., 2013). The implications of disasters on the psychosocial needs of the impacted communities requires further consideration, aligning with best practice identified in the Sendai Framework for Disaster Risk Reduction (UNDRR, 2015), though was considered out of scope for this thesis. The Ministry of Health, mandated to coordinate psychosocial support after disasters (in both urban and rural settings), has published both the National Health Emergency Plan (Ministry of Health, 2015), and the Framework for Psychosocial Support in Emergencies (Ministry of Health, 2016). While these documents provide overall strategic guidance for the health sector, they remain framed within the health context and are not well integrated into the wider field of DRM.

The tension between these divergent response priorities became particularly evident when road cordons were put in place to minimise the risks to life and safety of road users, as per CDEM priorities and mandate. Rural communities were more tolerant of, and better prepared for, off-road travel, and road cordons in effect made it difficult for them to implement their own response priorities, including the acquisition of food and water for livestock welfare needs. Efforts by MPI representatives to intervene on behalf of different rural actors wishing to obtain access past the cordon underline the divergent priorities awarded by CDEM and MPI legislation. Where MPI is required to support many rural industries in an ongoing manner, scaling their response to larger adverse events, it is not responsible for disaster response as such in rural regions, and there is no provision in legislation for alignment with CDEM response and recovery operations. Conversely, the CDEM Act 2002 does not distinguish between urban and rural based response and recovery operations. While it does, however, provide for the hierarchically organised coordination of response and recovery actors, in practice these actors are largely those featuring in urban response and recovery. Where MPI is required to develop extensive rural networks in support of rural industries, these networks include a wide range of response and recovery actors in government, private, and community sectors, and are encouraged (and in some cases funded) by MPI to self-organise from the bottom up. This creates a structural misalignment as well as differing priorities between the response efforts of these two agencies.

Moreover, governance of disaster related risk in rural regions is also shared with other agencies under multiple Acts, such as the Resource Management Act (1991), the Earthquake Commission Act (1993), and the Building Act (2004). Therefore, much clearer mechanisms for whole-of-government integration and coordinated response are urgently required (Basher, 2016). The resulting overlapping and/or parallel sets of legislative responsibilities was evident in the disaster response to the Kaikōura earthquake, where many of the rural response organisations linked to MPI acted independently of the coordinated CDEM response. Perhaps in an attempt to address perceived gaps in the government response, rural regions self-organised by forming co-called 'primary industry clusters,' such as TeamAg and the pre-existing local Drought Committee, to help with the earthquake response. These groups were highly active in the same space as the CDEM response, but were not part of the official government response framework. The capacity to self-organise is a characteristic common of rural communities and sectors (Bruneau et al., 2003; Berkes and Ross, 2013; Waugh, 2013), and MPI appears to encourage this manner of addressing locally-identified gaps in the response by funding many of these initiatives (MPI, 2017).

The coordination of the wide range of agencies, organisations, businesses, and individuals involved in the earthquake response and recovery (including representatives from multiple government agencies, non-governmental and private organisations, aid agencies, emergency services, disaster recovery specialists, volunteers, and research scientists) (Figure 3.4) would likely have been much easier to facilitate if clear integration pathways specified alignments with the CDEM response. A coordinating platform bringing local, regional, and national response actors together would have helped to minimise the misaligned priorities and confusion created by divergent CDEM and MPI legislative mandates. In the absence of such pathways, overlapping and intersecting roles and responsibilities between urban and rural agencies in the Kaikōura response operation created tension due to inherent differences in experiences and understanding of context. Each of these actors were found to had specific goals to address, and a distinct perspective on what is required for effective DRM. Urban emergency managers' experiences may not necessarily be directly transferable into the rural context, and rural response actors were often unaware of the rationale behind the CDEM legislative mandate. This increased the potential risks for rural communities in several areas. While these communities typically manifest a higher level of adaptive capacity when compared with urban communities (Bruneau et al., 2003; Waugh, 2013), the growing reliance of rural industries on

highly technical equipment and processes is reducing this capacity (Smith et al., 2011). Similarly, the absence of a coordinating platform to bring government and other response and recovery actors together meant that the environmental and financial context and implications created by the pre-existing drought was not initially evident to those responsible for coordinating the CDEM response effort.

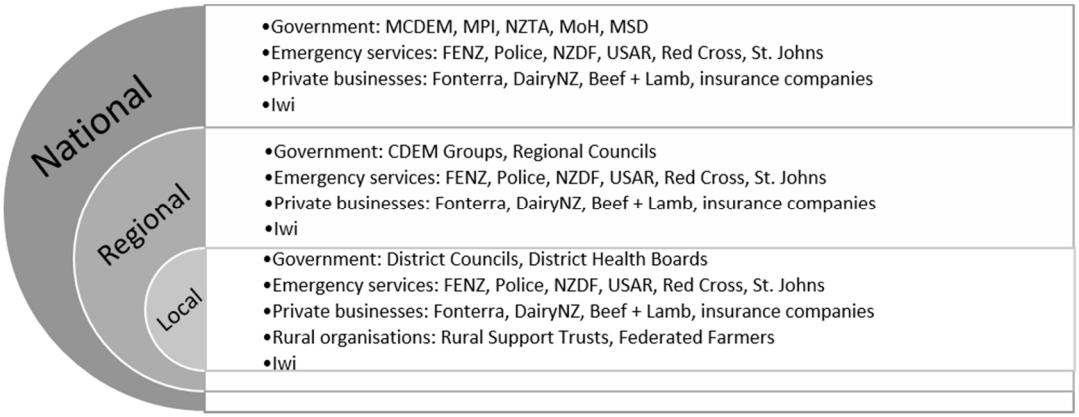

Figure 3.4 List of actors involved in the earthquake response and recovery, and the level at which they primarily operate.

The need for transparent coordination and integration pathways identified by Basher (2016) is particularly evident in the rural context. For rural residents and businesses, the legitimacy of response decision making was found to rely on the perception that their needs, interests, and knowledge are being factored into that decision making process, even if that means that help may not arrive immediately. Early acknowledgement of response delays is transparent, and concerns of rural interviewees would have been considerably alleviated by clear messaging concerning the timeframes within which help would arrive, and around road access and repair issues.

Additionally, the evolving nature of rural New Zealand also creates challenges for effective disaster-related governance and DRM implementation. Demographic studies from Statistics New Zealand (2017b) show a trend towards urbanization, as rural residents move to larger cities for school and employment, and towards an ageing population (Cochrane and Maré, 2017). There is also increasing intensification of farm yields to maximise profits (World Bank, 2006). To realise efficiencies in production, farms will produce a single crop variety (Feintrenie et al., 2010), thereby increasing their vulnerability to crop-specific hazards (e.g. poorer drought resistance from water intensive crops) (Beeton and Lynch, 2012). The hazard

risk to such monoculture farms will likely increase given the growing role of climate change. Current trends of centralizing services means that rural farms and businesses become more heavily reliant on a vulnerable road network, increasing their chances of isolation during an event (Christopher and Peck, 2004; Miguel et al., 2015). This continually changing demographic, environmental, and technological make-up of the rural regions in New Zealand creates a challenge to building resilience through DRM. The full extent of these disaster risks have not yet been fully understood, as rural DRM is nationally understudied and a gap in the knowledge domain (Spector et al., 2018).

3.7. Conclusion

The response and recovery to the Kaikōura earthquake took place in a complex, multi-hazard context, and exposes some of the broader issues with New Zealand's rural DRM practices. While this event affected multiple regions, it mostly affected rural regions, therefore the interface of rural organisations and urban-based DRM specialists can be commented on. This study supports the argument that effective DRM and disaster response in rural areas must be informed by rural needs and perspectives and must acknowledge the distinct context in which rural disasters occur.

The divergent response priorities between the government-led response structures and rural organisations was aggravated by a lack of coordinating platform for local, regional, and national communication. While completely integrative mechanisms are rare in most disaster responses scenarios nationally (and internationally), this is especially important in the rural context as such a mechanism could help coordinate a broad range of actors who may not be familiar with rural-specific needs and priorities. For example, the CDEM focus on the provision and distribution of human welfare needs (such as food, potable water, and temporary shelter) makes sense in an urban earthquake setting, but this focus is less appropriate in rural contexts, not just because the population density and numbers are lower, but because rural populations are often more prepared for isolation, and may not require welfare distribution.

While there is undoubtedly a need for administrative regulation and governmental oversight in rural DRM, legislation can, at times, impede the use of local knowledge during a response. Finding the right balance between legislation which enables DRM and disaster response, rather than constraining it, is a challenge in every context, but requires specific

attention to address the variety of considerations specific to the rural environment. For example, emergency response efforts by CDEM to engage with isolated rural communities were hindered by the CDEM priority (and mandate) to help the maximum number of people in the shortest amount of time, putting sparsely populated rural regions at a disadvantage. A comprehensive understanding of the rural sector and associated disaster risk drivers is required for emergency managers to effectively respond to disasters in rural regions, ensuring proper consideration of local economic, social, and environmental elements.

The complexity of disaster response in rural New Zealand, as shown by this case study, demonstrates the need for a rural lens on the country's DRM practices. As much of New Zealand's economy flows through rural areas (including transport of goods, agricultural service sector, and tourism flows), this represents a high level of vulnerability for the nation. At the same time, evolving social, economic, technological, and natural environments in rural communities across the country continue to create new vulnerabilities which must also be identified, understood, and incorporated in future rural DRM in New Zealand.

3.8. Acknowledgements

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Chapter Four - Knowledge sharing in interdisciplinary disaster risk management initiatives: co-creation insights and experiences from New Zealand

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Preface

The previous chapters investigated impacts to rural communities and sectors following the 2016 'Kaikōura' earthquake (Chapter 2), and argues the need for rural perspectives to drive rural disaster risk management (Chapter 3). This next chapter will build on Chapters 2 and 3 by considering *how* rural perspectives can best inform and be included in disaster risk management practice and policy.

4.1. Abstract

Decision-making in complex contexts such as disaster risk management requires more collaborative approaches to knowledge production. Evidence-based disaster risk management and pre-event planning relies on robust and salient disaster risk knowledge. Generating such knowledge relies on the processes used at the interface between scientists and practitioners. This study uses a case study to examine the processes used to generate, share, and apply multi-disciplinary disaster risk knowledge in a 'co-creation' collaboration involving practitioners and scientists in a New Zealand context. Project AF8 was conceived as a cross-jurisdictional and multi-agency initiative to plan and prepare for a coordinated response across the South Island following a large magnitude earthquake along the Alpine Fault – considered one of New Zealand's major natural hazard risks. Interviews with emergency management practitioners and scientists at local, regional, and national levels are used to investigate the use of the Project AF8 framework to co-create disaster risk knowledge. Results show that (1) emergency managers at all levels operate in highly uncertain environments and therefore have specific knowledge needs at different times, (2) disaster risk knowledge is most effective when scientifically credible and focused on understanding the 'functional experience' expected following an event, and (3) while disaster risk knowledge outputs are valuable, the processes through which this knowledge is co-created are equally important. The use of a co-creation process to combine credible research findings with relevance to practitioner needs enhanced the legitimacy of Project AF8 processes and the knowledge it generated. These processes would have benefitted, however, from the collaborative development of a formal co-production structure at the outset. If managed properly, similar future interdisciplinary initiatives worldwide could benefit by adopting contextually relevant aspects of this example to strengthen the science-practice interface for more effective pre-event planning and decision-making.

4.2. Introduction

Losses from disasters continue to rise globally with implications for human well-being and livelihoods (Cutter et al., 2015; Tanner et al., 2015). To address this, two trends in disaster risk reduction (DRR) and resilience science are attempting to address this, with science defined as the "systematic approach to the creation of new knowledge" (Chalmers, 1976, as cited in

Wyborn et al., 2017:5). Both these trends are in line with the recommendations of the Sendai Framework for Disaster Risk Reduction. Firstly, the analytical focus has shifted towards analysing the underlying drivers of disaster risk, including hazards, vulnerability, and exposure (Fekete et al., 2014; Mechler and Bouwer, 2015; Thomalla et al., 2018) and identifying and evaluating the effectiveness of mitigation and adaptation strategies (Paton and Johnston, 2001; Briceño, 2015; Koks et al., 2015). Secondly, multi-disciplinary teams that include both practitioners and scientists are increasingly being used to co-design DRR and resilience solutions (Aitsi-Selmi et al., 2016; UNDRR, 2019). Examples include New Zealand's DEVORA programme for volcanic eruptions (http://www.devora.org.nz/), and the United Nation's Integrated Research on Disaster Risk programme (http://www.irdrinternational.org/) for all natural and human-induced hazards.

Internationally, a number of such multi-agency and interdisciplinary initiatives have arisen in the past ten years aimed specifically at earthquake resilience (Table 4.1). Despite the significant investment in these and other initiatives, there are limited documented academic studies which evaluate their effectiveness, particularly with regards to how knowledge is produced, shared, and used among disaster risk management policy-makers and practitioners.

Table 4.1 Examples of large earthquake-focused multi-disciplinary initiatives since 2008, involving disaster risk management decision makers, scientists, and public stakeholders.

Initiative (country)	Goal	Funding amount	Status	Timeline
Project AF8 (New Zealand)	Improve the response capability of regional agencies, and develop an operational plan to support the response.	$490,000 NZD (~$319,800 USD)	Active	4 years, June 2016 to June 2020
East Coast LAB (New Zealand)	Multi-agency initiative to improve resilience to communities on the East Coast from off-shore natural hazards including the Hikurangi trough.	$240,000 NZD (~$156,600 USD)	Active	1 year, July 2018 to June 2019
It's Our Fault (New Zealand)	To see Wellington become a more resilient city through comprehensive study on earthquake likelihood, effects, and impacts.	~$450,000 NZD annually (~$163,200 USD)	Active	Ongoing, since 2006
Real Time Earthquake Risk Reduction (EU)	Improve preparedness for earthquake hazards by enhancing real-time risk mitigation and establishing methodologies for practitioners.	~€10.1 million Euro (~$11.3 million USD)	Complete	3 years, September 2011 to December 2014
Increasing Resilience to Natural Hazards (UK)	To build resilience in earthquake-prone and volcanic regions by reducing risks from multiple	~£8.3 million pounds	Complete	8 years, 2010 – 2018

	natural hazards and increasing population resilience to high impact events.	(~10.78 million USD)		
Science for Humanitarian Emergencies and Resilience (UK)	To improve the characterisation of the hydrological controls on natural hazards thereby enabling better prediction of their occurrence and scale, with a focus on landslide risk.	~£19 million pounds (~24.68 million USD)	Ongoing	7 years, 2015 – 2022
Hayward Fault Initiative (USA)	To promote risk reduction locally, by providing information on earthquake consequences and encouraging risk reduction programs.	N/A	Complete	Original in 1996, updated in 2010.
Haywired	Scenario development to advance risk analysis and inform disaster planning (preparedness, response, and recovery).	N/A	Active	2017 – present.
Great Southern California ShakeOut (USA)	Earthquake drill to increase public awareness and understanding of response.	N/A	Active	Annual, since 2008
The SZ4D Initiative (formerly 'Subduction Zone Observatory') (USA)	Understanding the processes that underlie subduction zone hazards in four dimensions.	$4.9 million USD	Active	3 years, September 2018 to August 2021

Researchers can find it difficult to successfully navigate this new approach, particularly if they understand their role as generating scientific disaster risk information to be delivered to decision-makers (Doyle et al., 2015; Kete et al., 2018). To enhance strategic DRR planning the goal is to co-create shared knowledge that is robustly scientific while also meeting decision-making needs (Aitsi-Selmi et al., 2016; Aldrich, 2019; Djalante et al., 2011).

This research used an in-depth case-study analysis of Project AF8 to improve understanding of the benefits of, and challenges and barriers to co-creating disaster risk knowledge that is both relevant and scientifically robust. This cross-sector, multi-disciplinary research initiative in New Zealand focused on the development and implementation of scientifically robust earthquake scenario-based emergency response preparation and planning for a large-magnitude Alpine Fault rupture (Orchiston et al., 2018). The Alpine Fault is considered a major natural hazard risk for New Zealand (Orchiston et al., 2016), particularly for the predominantly rural communities and industries in the South Island. A rural earthquake in the South Island (the 2016 Mw7.8 'Kaikōura' earthquake) occurred shortly after the inception of Project AF8. This event provided valuable lessons for the Project AF8 initiative concerning the potential rural impacts of a major regional earthquake on national and local distributed infrastructure networks, rural and isolated communities, primary industries (pastoral farming,

viticulture, and seafood sectors), and the tourism sector (which relies heavily on New Zealand's natural environment) (Stevenson et al., 2017). The following chapter draws on the results of interviews and participant observation to document the processes and content of disaster risk knowledge generated through the AF8 initiative. The aim is to gain insight into the processes used to navigate the interface between science and practice, the knowledge that was co-created in this way, and to identify best practices applicable in other national and international contexts.

The paper is organised as follows: an overview of disaster risk communication and the interaction between science and practice is next. This leads into a discussion of the need for legitimacy in the production of disaster risk information. Project AF8 is introduced along with an overview of the research methodology. Findings are discussed in terms of (1) focus and content of disaster risk knowledge and (2) the co-creation processes used to manage the science-practice interface, and are followed by conclusions and recommendations.

4.3. Disaster risk information, shared knowledge, and the science-policy-practice interface

The United Nations defines disaster risk information as information on all dimensions of disaster risk, including hazards, exposure, vulnerability, and capacity, related to persons, communities, organisations, and countries and their assets (UNDRR, 2015*a*). It includes all studies and mapping necessary to understand disaster risk drivers and underlying risk factors (UNDRR, 2015*a*). Scientifically credible disaster risk information is widely seen as the core of effective disaster risk management (Calkins, 2015). Disaster risk management (DRM) is the holistic application of DRR policies and strategies to prevent new disaster risk, reduce existing disaster risk, and manage residual risk (UNDRR, 2015*b*). Disaster risk management requires the sharing of disaster risk information between practitioners and researchers to advance risk awareness and understanding, and facilitate DRR behaviours (DiClemente and Jackson, 2016; WHO, 2019).

Over the last few decades, the style and content of disaster risk information has evolved towards better experiential content and format from 'hazard'-, to 'damage'-, to 'functional' experience (World Bank, 2012). From a focus centred on the physical properties of events (e.g. intensity, spatial extent, frequency, probability) disaster risk research across multiple disciplines has recognised that consideration of extent and severity of impact to society (e.g.

damage and disruption), and the role of potential mitigation and adaptation strategies, are both more useful and useable within disaster risk reduction (World Bank, 2012; Simpson et al., 2014; EERI, 2008). In particular this has been led by the growing recognition of the extent to which disasters, although triggered by natural hazards, are inherently social processes (White et al., 2001).

Recognising disasters as complex events, this change in informational demands places greater emphasis on understanding interdependencies between social, built, cultural, political, economic, and natural environments (EERI, 2008; Gaillard and Mercer, 2013; Komendantova et al., 2014; Guidotti et al., 2016; Paton and Buergelt, 2019). This trend is mirrored in the Climate Change Adaptation (CCA) domain, where research confirms that impact-based approaches to disaster risk information are more effectual at influencing policy and practice, as compared to hazard-based approaches (Wisner and Walker, 2005; Schipper and Pelling, 2006; Mercer, 2010; Cradock-Henry et al., 2019; Leitch et al., 2019).

Recent research has highlighted different ways of understanding the processes and settings in which policy makers, practitioners, and others, receive, use, or do not use scientific research when making decisions (Huggins and Johnston, 2015; Wyborn et al., 2017; Crawford et al., 2019). The conventional 'knowledge deficit model' assumes that scientific information can be simply transferred to policy-makers and practitioners who will use it to inform evidence based decisions (Cash et al., 2006). However, this view of communication is overly simplified and increasingly accepted as insufficient, particularly when dealing with a complex issue like disaster risk management (Cash et al., 2003; Cash et al., 2006; Sinclair et al., 2012; Scheufele, 2013; Wyborn et al., 2017; Fearnley and Beaven, 2018; Doyle et al., 2019; Sword-Daniels et al., 2019). In these environments, it has been established that interactions and processes between science, policy, and practice are usually complex, dynamic, vary widely, and are continually negotiated (Wyborn et al., 2017). Recognition of this reality is increasingly leading to much more collaborative and iterative approaches to managing the science-policy-practice interface (Wyborn et al., 2017). Science engagement approaches of this kind include what is known as 'co-creation,' which has been defined as the process of jointly producing knowledge with one or more others (Mauser et al., 2013; Rock et al., 2018). It has been established that using formal structures to balance the interests and influence of all those involved in the co-creation can enhance the scientific credibility of the resulting knowledge, while the consideration of appropriate values, interests, concerns, and circumstances from multiple

perspectives enhances relevance and legitimacy (Cash et al., 2002; Cash et al., 2003; Lacey et al., 2018). The co-creation processes have a strong influence on the extent to which knowledge is perceived to be scientifically credible, of practical use, and legitimate (Cash et al., 2002; Fearnley and Beaven, 2018). It has recently been argued that the legitimacy of disaster risk information relies on balancing the practical knowledge and professional experiences of practitioners and policy makers with the robustness and credibility that scientists bring to the collaborative process (Fearnley and Beaven, 2018).

Growing awareness of the need for collaborative approaches is informing efforts to support large cross-sector and interdisciplinary initiatives in order to address complex, global issues, such as DRR. These are often focused on enhancing more effective communications of risk information from scientists to practitioners and policy makers. However, analysing collaborative efforts of this kind as co-creation initiatives, rather than more narrowly as communication of science, offers to provide insights into their effectiveness, document challenges and successes, and provide practical guidance for future efforts.

This is the approach taken in this article, which investigates the development of a New Zealand multi-agency cross sector collaboration, Project AF8, as a co-creation initiative. The following section introduces the New Zealand context, and Project AF8, which is focused on preparing agencies and communities for an expected large magnitude earthquake in this country's South Island.

4.4. Case study context

New Zealand is a small tectonically active nation in the Southern Pacific, with a history of frequent seismic activity (MCDEM, 2007). Earthquake hazard and risk has been long recognised in New Zealand, informing initiatives aimed at reducing this risk. These include disaster risk governance, including land use planning (IFRC, 2014); strict enforcement of high seismic standards in building codes (New Zealand Legislation, 2019a); a well-developed emergency management sector (MCDEM, 2017b); relatively high public levels of disaster awareness (MCDEM, 2016); very high levels of insurance uptake (Insurance Council of New Zealand, 2018); and sustained investment in hazard and risk assessment (Cowan et al., 2008; EQC, 2019).

The South Island of New Zealand has a population density of ~7.3 people per square kilometre (Statistics New Zealand, 2019), including a widely distributed network of rural communities which are highly dependent on a distributed critical infrastructure system (New Zealand Treasury, 2015). Much of the nation's economy stems from primary industries and associated farming service sector, accounting for 7.5% of gross domestic product in 2015, and 79% of national exports (Statistics New Zealand, 2017). Since this production occurs predominantly in rural regions, the impacts of a large magnitude earthquake on rural communities can have national implications (Spector et al., 2019).

Over the last decade, two earthquakes in New Zealand have resulted in 187 fatalities (185 due to the 2011 Christchurch earthquake and 2 caused by the 2016 Kaikōura earthquake) and thousands of injuries (Johnston et al., 2014; MCDEM, 2017a; Horspool et al., 2019). While tragic, this death and injury toll is comparatively low when compared to similar magnitude earthquakes in countries with higher populations and less well developed earthquake risk reduction initiatives, such as the estimated 316,000 fatalities reported following the 2010 Haiti earthquake (Sadiq and McEntire, 2012). However, the disruptive effects of these disasters on local, regional, and national communities has been particularly costly in monetary terms (NZ$25 billion/US$16.8 billion in insured losses [ICNZ, 2019]) and also in social capital (Stevenson et al., 2011; Stevenson et al., 2017). Recent government mission-led initiatives aim to increase the creation and uptake of scientific knowledge to address a number of complex issues, including rising disaster losses. A notable example is the 10-year 'Resilience to Nature's Challenge' National Science Challenge (MBIE, 2019). A number of other specific projects focus more narrowly on the risks posed by particular sources of natural hazard (Thompson et al., 2017), including Project AF8.

4.4.1. Project AF8

Project AF8 (AF8) is a large cross sector, interdisciplinary, multi-agency, and cross-jurisdictional initiative addressing a potential magnitude 8.0 earthquake along the Alpine Fault (AF) (Orchiston et al., 2016). The Alpine Fault is a plate boundary fault that runs the length of the South Island. Highly active, and 350 kilometres long, this fault has been a sustained focus of research (Cooper et al., 1987; Bull, 1996; Norris and Cooper, 2001; Berryman et al., 2012; Howarth et al., 2018), and of emergency management policy and practice due to the risk it poses

(MCDEM, 1990; Orchiston et al., 2016). Recent scientific studies have identified there have been 27 seismic events over the last 8,000 years on the southern segment of the AF (Cochran et al., 2017). This evidence provides a 29% conditional probability of that segment rupturing again within the next 50 years (Cochran et al., 2017). A full length rupture along the AF (moment magnitude 8.0) is expected to generate strong initial ground shaking, a long and potentially complex aftershock sequence, and co-seismic hazards including landslides, landslide dams and subsequent outburst flooding, lake seiches, liquefaction, and large-scale sediment transport and aggradation in rivers; with the impacts of these hazards expected to have national implications (Robinson and Davies, 2013; Robinson et al., 2016).

Project AF8 was conceived as a collaborative effort to reduce the impacts of such an event by planning and preparing a coordinated response at the local, regional, and national levels. The project combines scientific modelling, emergency response planning, and community engagement to better understand the hazard consequences to the people, communities, industries and infrastructure of the South Island. The project is led by a dedicated project manager, and direction is supported by a Steering Group including that manager, one lead scientist, and six senior emergency managers (one from each of the South Island regions' Civil Defence and Emergency Management (CDEM) Groups). CDEM Groups are a regional consortium of local authorities, emergency services, lifeline utilities, and government departments, required under the CDEM Act (2002) to coordinate regional and local DRR efforts. Project AF8 is unusually cross-jurisdictional in that it is the first project to regularly bring representatives from a number of different CDEM Groups together. Each CDEM Group representative on the Steering Group liaises with their respective teams of contributors and stakeholders across the South Island as per the CDEM Group structure. The lead scientist liaises with those members of the New Zealand science community who contributed to scenario development, on-going applied research in support of the AF8 mission, and subsequent community engagement. This allowed AF8 to draw on professional emergency management experience and contextual insights into, and oversight of, disaster response operations from across the South Island, as well as relevant hazard and risk physical science, engineering, and social science expertise (Orchiston et al., 2018).

The project is organised around three main objectives relating to a large AF earthquake: to improve understanding of the consequences of a future event, to increase the readiness and response capabilities across the South Island, and to engage and share learnings with the wider

public (see https://af8.org.nz/). It supports delivery of these objectives firstly through the creation of a maximum credible event scenario, which uses up-to-date scientific knowledge on seismic hazards and impact modelling to outline the likely impacts of a given magnitude 8.0 AF earthquake. Secondly, AF8 maps out a cross-jurisdictional and multi-agency approach to the response to enhance efficiency. Finally, AF8 engages with the public and interested organisations through a public education campaign.

The science investment in AF8 builds upon decades of national disaster risk and emergency management policy iterations (e.g. the Civil Defence Emergency Management Act 2002), multiple research programmes and funding initiatives (e.g. the National Hazards Research Platform, Resilience to Nature's Challenge, QuakeCoRE) (see https://www.naturalhazards.org.nz/, https://resiliencechallenge.nz/, and http://www.quakecore.nz/, respectively), and recent practitioner experience with disasters (e.g. the 2010 – 2011 Canterbury Earthquake Sequence). This investment strategy is consistent with international trends, where research that addresses societal issues (e.g. the European Commission's 'Societal Challenges,' see https://ec.europa.eu/programmes/horizon2020/en/h2020-section/societal-challenges), and uses co-production to bring science, policy, and practice together, is becoming mainstream. Within New Zealand's DRM sector, these trends are evident in several large multi- and inter-disciplinary research projects which inform natural hazard risk management strategies. Examples include the 'It's Our Fault' (https://www.gns.cri.nz/Home/IOF/It-s-Our-Fault) and 'East Coast Lab' (https://www.eastcoastlab.org.nz/) programmes for earthquake hazards, and 'DEVORA' (http://www.devora.org.nz/) for volcanic hazards (see also Table 4.1).

The first objective for AF8 was to collate current scientific knowledge to develop a scenario that could inform emergency response planning (Orchiston et al., 2018). Scientists were tasked by the AF8 Steering Group with creating a "maximum credible" AF event scenario. The lead scientist and a small (~ 5 person) group of scientists involved in the conception of the project developed a methodology to a) identify the greatest sources of uncertainty (and gaps) in current disaster risk information (including hazard, impact and risk assessment knowledge), b) create an inclusive process which utilised all available/willing AF scientists, and c) determine what disaster risk information was most important for emergency managers with respect to scenario content (Orchiston et al., 2018). This stage of AF8 was heavily informed by expertise and knowledge developed in the lead up to the 2013 Exercise Te Ripapaha, which was an

Alpine Fault response exercise on the South Island that only included CDEM organisations (Robinson et al., 2013).

Selected Steering Group emergency managers and thirty five scientific experts convened in late-2016 for a scenario-building workshop. The workshop was organised according to the three central aspects of the scenario: earthquake source (e.g. epicentre, ground motion), geomorphic consequences (e.g. landslides, surface deformation), and impacts on social and built environments. Discussions began using talking points drawn from a 'strawman' scenario, developed by the early scientist group, to provide preliminary guidance and direction. Scientists discussed the potential variability of a magnitude 8.0 AF earthquake, and settled on specific values for use in the scenario.

Project AF8 Steering Group members provided input regarding information needs over the two-day workshop, including the depth and breadth of the content required for each aspect of the scenario. Discussion between emergency managers and scientists provided a forum to explore availability of existing and future possible disaster risk information, and the needs and uses of a scenario for practitioners. The workshop concluded with a short-term work plan to refine and finalise the scenario, upon which CDEM response planning would occur.

The first iteration of the scenario was delivered to the Steering Group three months later (Orchiston et al., 2016) (Figure 4.1). Throughout 2017, the scenario was refined through subsequent workshops with each of the six South Island CDEM Groups, to better suit stakeholder needs by adding local and regional level impacts, building off the base hazard and impact scenario. These workshops were led by the relevant CDEM Group, supported by the presence of two to three scientists, and involved representatives from local government, infrastructure providers, health and social services, the private sector, and Iwi. Iwi are indigenous New Zealand tribal organisations with a suite of traditional rights and responsibilities arising from historical and contemporary interests in a particular rohe or area (http://www.tkm.govt.nz/glossary/). In this officially bicultural nation, agencies govern in formal statutory partnerships with relevant Iwi (http://www.tkm.govt.nz/glossary/). The workshop format included a presentation of scientific knowledge on the likely consequences of an AF earthquake, contextual information for each setting, and an opportunity to discuss additional information needs. Feedback was considered by the presenting scientists who then incorporated it into the scenario incrementally over the course of a year.

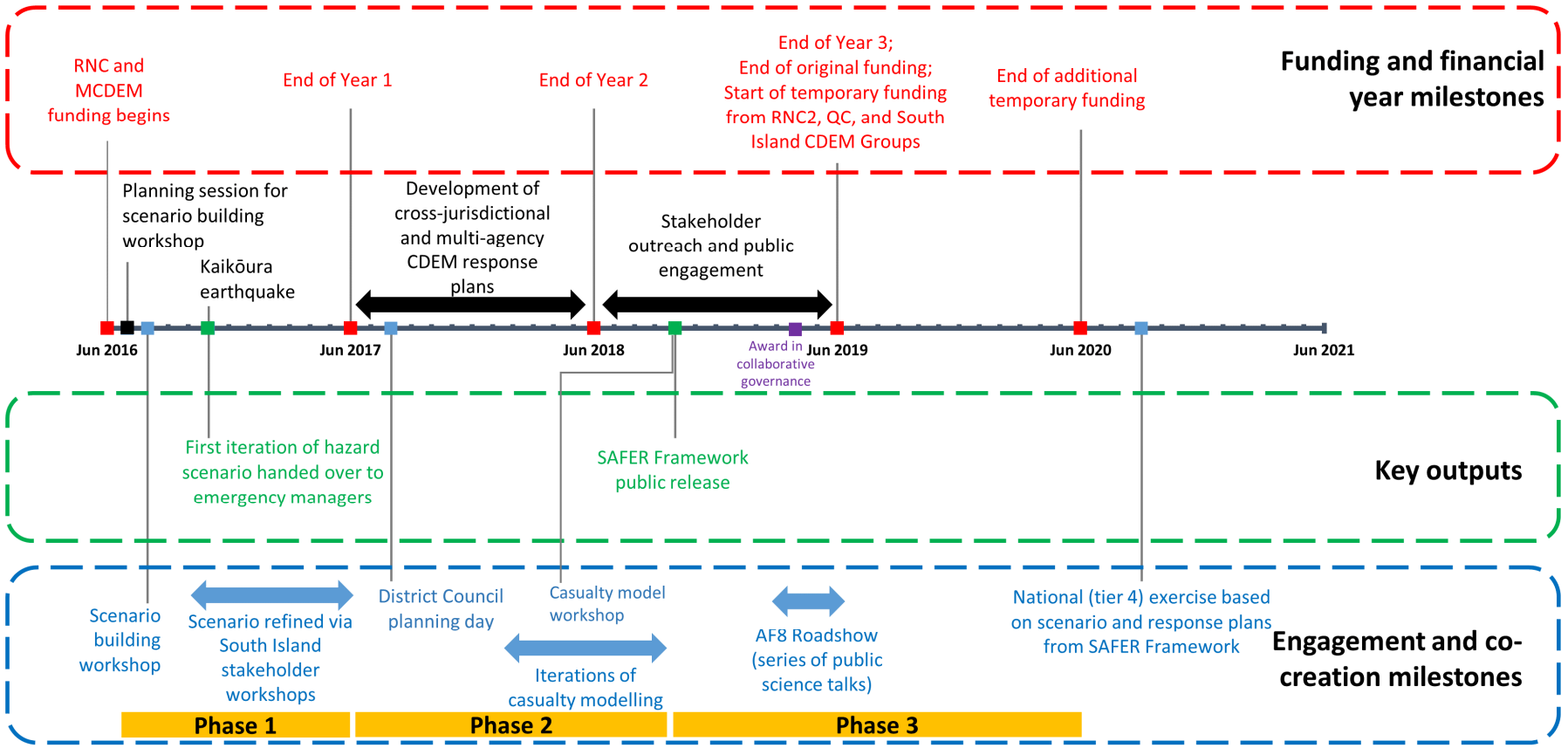

Figure 4.1 Detailed timeline of major Project AF8 milestones, including key moments of the funding cycle, main generated outputs, and important aspects of the engagement process.

In the second year of the project, facilitated discussions between the six CDEM Groups were held to enhance multi-agency AF response across jurisdictional boundaries. The resulting emergency response priorities were combined with the scenario that had been created through iterative co-creation between scientists and emergency manager stakeholders during the first year of the project, to form the South Island Alpine Fault Earthquake Response (SAFER) framework (https://af8.org.nz/safer-framework/). This document presented a timeline of estimated response challenges within the first seven days of an event, and mapped out a set of synergistic operational objectives for all six South Island CDEM Groups.

The first two years of the project were dedicated to synthesis and planning. The third objective – outreach and communication – was the focus in Year 3. Enhanced public awareness was achieved through a series of public talks – the AF8 Roadshow – and presentations to secondary school classrooms. The South Island-wide campaign addressed growing public demand for disaster risk information, giving rise to ongoing requests for presentations to community groups, schools, and organisations. At the time of writing (late 2019), over 150 AF8 presentations have been given, reaching an audience of nearly 9,000 people (Project AF8, 2019). In April 2019, AF8 won the BERL Award for excellence in Collaborative Government Action from the New Zealand Society of Local Government Managers, highlighting the achievements of the project (SOLGM, 2019). The value of the collaboration and contact between South Island emergency managers stimulated by AF8 has prompted exploration of transitioning this three year project into an ongoing 'Programme AF8.'

4.5. Methods

To gain insight into the effectiveness and performance of the AF8 approach to the knowledge production process, this study used interviews, a focus group, document analysis, and participant observation.

Participant observation included involvement by the author in the early development of the strawman scenario used in the initial AF8 workshop, as well as attendance, observation, note taking, and in some cases active participation in a selection of subsequent AF8 meetings.

A total of n = 20 semi-structured interviews were conducted by the lead author with a purposive sample of participants. Interview participants were identified and recruited based on

their professional involvement in AF8, and included AF8 Steering Group members. Participant observation of the process was supplemented by three interviews with key academic scientists centrally involved in Project AF8. The majority of interview participants (n = 17) were practitioners and policy makers spanning local, regional, and national levels (Table 4.2). Open-ended questions were designed to gauge perceptions of the extent to which co-produced disaster risk knowledge from the AF8 initiative was perceived to be scientifically credible and also relevant enough to be used by practitioners and policy makers in day-to-day tasks. Questions for practitioners and policy makers also focused on the application and performance of generated AF8 material at different levels and in different roles (such as council employees within local and regional government), including perspectives on optimal risk measurement metrics. Interviews were mostly face-to-face, but also over the phone when necessary.

Additionally, an AF8 Steering Group focus group (n = 5) was conducted with the project manager, the lead scientist, and three of the six CDEM Group representatives. The discussion addressed questions similar to those used in interviews. Data was collected between September 2017 and August 2018. Ethical review and approval was obtained from the University of Canterbury's Human Ethics Committee (reference number: HEC 2017/34/LR-PS).

Table 4.2 Role and distribution of interview participants.

	Operate:		
	Locally	**Regionally**	**Nationally**
Practitioners	4	9	1
Policy makers	-	1	2
Scientists	3		

Interviews progressed through the use of the 'snowballing' technique and ended once the authors determined data saturation had occurred. The focus group and all interviews were recorded and in most cases professionally transcribed, then cross-referenced by the lead author and validated by the participants. Transcribed data was manually and iteratively coded using spreadsheet software and an inductive process. Themes relating to information transfer, interfacing, and project outcomes were identified first by the lead author following multiple readings, and then discussed amongst all authors.

Transcription and analysis was supplemented with participant observation. Project AF8 outputs (e.g. impact maps) were then reviewed to contextualize the results, and shed light on the results of the Project AF8 co-creation process. Disaster risk information outputs were read,

contributed to, and in some cases produced by two of the authors, then discussed with end-users as part of interview process.

4.6. Findings

Results reveal two important considerations regarding disaster risk information: first, content matters. Disaster risk knowledge is particularly useful to practitioners and policy makers when it addresses how an event might impact vulnerable populations, or affect the functionality of exposed infrastructure, since impacts inform the operational logistics of an emergency response. Second, the process used to identify, generate, and disseminate disaster risk information is equally vital to ensuring that content is fit-for-purpose and used by practitioners. The engagement process used both within AF8 (to manage interactions between members) and during AF8 outreach (to manage interactions between AF8 and the public) was a key element in the success of the project. We discuss both of these considerations in turn.

4.6.1. Disaster risk knowledge

Interviewed participants identified needs and priorities for the disaster risk knowledge generated through AF8. These included understanding potential disaster impacts to populations (i.e. individuals and communities) and to the built environment. Disaster risk knowledge of these two areas contributed to practitioner and policy maker pre-event planning by increasing their understanding of the logistical environment in which the response is likely to take place.

The disaster risk knowledge needed to encompass the first theme, which centred on the needs of individuals and communities, included aspects of human health, basic necessities such as food and water, and the effects of isolation. A senior regional practitioner explained that disaster risk knowledge must "ultimately [relate to] the lives of the people, so anything around those vulnerabilities (…), from our planning perspective is very, very useful."

Disaster risk knowledge regarding the second theme was partially achieved through early AF8 modelling efforts. Maps detailing the expected loss-of-service to critical infrastructure (such as the co-seismic hazard maps found in Robinson [2014]) were well received, and built on pre-existing Alpine Fault rupture scenarios which were largely

qualitative. Every practitioner and policy maker interviewed wanted AF8 to provide a broad understanding of likely disaster impacts on critical infrastructure and lifelines networks (such as telecommunications, roads and bridges, water supply, and electricity). Knowledge of the way that critical infrastructure was likely to perform during and after a disaster was identified as crucial for response planning and post-event logistics. Interviewees described disaster response as hinging on the access required to move victims away from hazard zones and to bring in vital goods and rescue specialists. The consensus was that planning an effective earthquake response across the South Island relies on understanding where key infrastructure is likely to experience a loss of service. While the regional Robinson (2014) hazard and exposure maps were useful in a simplistic sense, they were not fully applicable for the detailed purposes of AF8.

As the AF8 initiative progressed, the focus of disaster risk knowledge improved to better align modelled products with the specific needs of practitioners and policy makers. For example, one researcher engaged with stakeholders to refine infrastructure outage modelling and detail impacts at the community level (Davies, 2019). A practitioner explains:

> What I want to know is what's that [event] going to look like on the ground? What am I going to be faced with? Are we still going to be able to drive through that area? (…) What does that mean for that community? Are they trapped, are they out of power, are they out of water and all of those things? I can put plans in place to deal with that, I can put plans in place before it happens. There's a lot of pre-planning that we can do around that, and even if it's loose numbers.

According to interview participants, modelling that informs on the functional capacity of infrastructure following a disaster was needed, as it relates more immediately to the resilience of impacted communities.

Community level impacts to infrastructure is just one of a number of examples in which the disaster risk knowledge developed through AF8 evolved to better encompass the likely functional consequences to society following a disaster. This focus was identified by study participants as being more useful for planning purposes than that of traditional hazard models (such as the modelling of peak ground acceleration or peak ground velocity), which, when used alone are, less likely to effectively facilitate the incorporation of scientific findings into the knowledge required to inform operational logistics. As practitioners put it:

> So the research into the hazard we understand is critical to get there, but for us the more useful part of it is the "so what," the implications of the hazards and the risks.

and

> I think you've got to take [hazard modelling] that next step further [to look at impacts], (...) you know this bridge would be destroyed, this bridge would be damaged, the entrances and exits would be damaged, the river might change course here or, this air field would be damaged for 12 hours, 48 hours. And I don't know if you can, but it would be really nice.

Participants all agreed on the value of pre-event planning and the benefits of impact models. They differed, however, according to individual views and professional needs as to the focus and breadth of disaster knowledge to be generated through the AF8 process. Examples of these bespoke needs are summarised in Table 4.3.

Table 4.3 Main uses of Project AF8 disaster risk information outputs to end of 2018.

Sector	Domain	Reported potential applications
Professional	Emergency managers	Pre-event response planning Post-event standard operating procedures Outreach Develop appropriate capabilities
	Government agencies and councils	Informs policy (such as those related to sustainable land-use management, building codes, health and safety, risk preparedness) Disaster prevention modelling and research by in-house technical staff Messaging to public
	Critical infrastructure agencies	Address network resiliency Informs on interdependencies between lifelines (such as roads, power, and telecommunications) Enhance business continuity
	Insurance agencies	Set premiums
Academic	Research institutions	Contribute to disaster risk reduction knowledge Support and contextualise future research needs
	Secondary schools	Lectures Student projects
Public		Family emergency plans Community readiness Enhance business continuity

Throughout AF8, all practitioners continued to need (modelled) disaster risk knowledge that concerned the initial hours (to days) following a disaster, since response coordination and operational decision-making immediately after a major event is based on the limited available early knowledge of the unfolding situation. AF8 disaster risk modelling of these early stages focused on informing early response plans and standard operating procedures, offering emergency responders a basis from which to make semi-informed operational decisions while

acting within an information vacuum. A senior practitioner explained that in the first twelve hours after a disaster:

> You're spending time trying to find out what the impact is. (…) If, in a perfect world, you had some modelling that could tell you, you might save a bit of time and be ready for it.

Of particular interest to AF8 practitioner and policy maker stakeholders was that this community impact and loss of service disaster risk information incorporate temporal dynamics into the modelling. Better understanding how these disruptions might evolve over time provide these stakeholders with enhanced capabilities to develop medium and long term response and recovery planning.

4.6.2. Engagement and opportunity

In addition to the focus and breadth of disaster risk knowledge, the processes through which this knowledge was conceived, developed, and shared by collaborating scientists and emergency managers was the key to its application in response and recovery planning. Stakeholders and scientists alike perceived the phased engagement process – involving first a small expert group, then wider emergency managers, and finally the public – to be an essential component of building trusting relationships between science and practice. Additionally, during the engagement phase with emergency managers, a large-magnitude earthquake struck the South Island, raising AF8's profile, accelerating fit-for-purpose scenario development, and promoting uptake (Woods et al., 2017; Wotherspoon et al., 2017).

4.6.2.1. Phased engagement process

The AF8 co-creation process progressed through three distinct phases, each involving different stakeholders to build on the previous phase (Figure 4.2). In Phase 1, scientists engaged with a core group of senior-level practitioners to co-create the initial scenario; Phase 2 iterated the scenario with input from a wider group of stakeholders including policy makers, critical infrastructure groups, and private businesses; and Phase 3 used AF8 outputs for public engagement and to enhance outreach, thereby generating additional interest and uptake of the disaster risk information created. As the project focused on the distinct goals and challenges of

each phase, new disaster risk knowledge was generated, partly through changing perceptions and experiences of the collaboration process. The nested phases of participation in AF8 by scientists, emergency management practitioners, policy makers, wider stakeholders, and the public was broadly consistent with participatory approaches to complex issues identified as best practice (Ross et al., 2002; Hurlbert and Gupta, 2015; Aoki, 2018). Iterative and adaptive, the AF8 process was for the most part situated towards the full co-creation end of the engagement spectrum (Ross et al., 2002; Hurlbert and Gupta, 2015; Aoki, 2018; Rock et al., 2018).

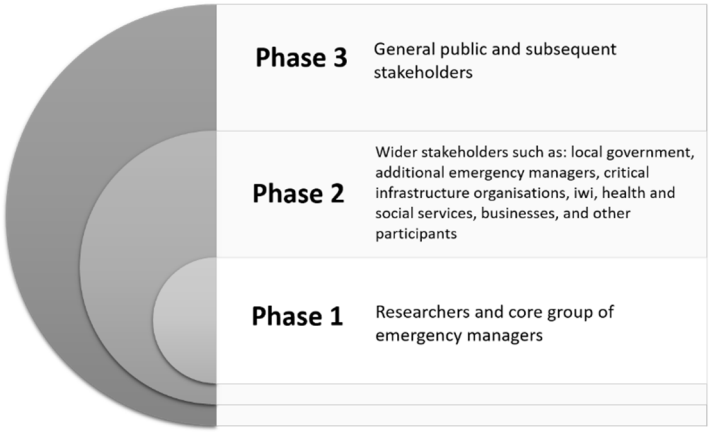

Figure 4.2 Nested phases of Project AF8 engagement process.

Phase 1 of the project focused on the interface between hazard scientists and practitioners. It began with a scenario building workshop, where senior practitioners from the Steering Group briefed the ~35 attending scientists on their informational needs for the content of the AF rupture scenario. The brief was necessarily high level rather than detailed, since the practitioners involved were not aware of the research capabilities of the scientific community. The scientists responded by brainstorming possible modelling options amongst themselves before putting a range of ideas to the practitioners present; this feedback was then the subject of further scientific discussions, in a series of back and forth iterations of alternative options between scientists and practitioners. This initial scenario-building workshop was a keystone element in the AF8 process, since it determined the scenario content. To this extent it was the foundation of subsequent knowledge development, disaster response planning sessions, and public engagement events across all three phases of AF8. Additionally, this workshop was the first interaction between scientists and Steering Group practitioners, and so helped to set the tone of subsequent AF8 co-creation processes.

Given the foundational status of this initial workshop, it would have benefitted from an established and well-defined collaborative framework to guide this first meeting. For example, scientists led a number of debates about some highly technical aspects of the AF, including possible directions for future modelling, that were forced to rely on informal and apparently ad-hoc engagement with attending practitioners to eventually better constrain and clarify the specific informational needs and uses of the scenario. This was time-consuming and an additional constraint on scientists required to meet a three month deadline to create the first full version of the scenario. As a result, there was not time to consider all the potential research ideas. Another effect of this informal early arrangement was that, while everyone in attendance agreed the scenario needed to be based on robust and up-to-date scientific knowledge, tension emerged amongst scientists since not every aspect of AF science would feature prominently within the scenario, due to the particular needs of the practitioners. Although some technical discussions were ultimately deemed out of scope for AF8, practitioner participants in this study considered the overall workshop to be highly successful.

Anecdotal evidence indicated growing levels of trust and intimacy developed during Phase 1. These laid a good foundation for future efforts, as one practitioner noted:

> I think for us to actually see what the capabilities of the science community are, and for them to actually see what our needs as practitioners are, has been a real win for the project.

Equally, the lack of a well-established, transparent, and widely agreed formal structure put additional pressure on the Steering Group, who required the lead scientist to 'manage' the scientists; had a formal structure effectively distributed roles and responsibilities among both science and practitioner groups, this requirement would not have arisen.

Phase 2 further refined the disaster risk information content of the scenario, by engaging with wider emergency management practitioners, policy makers, and other stakeholders such as local government, critical infrastructure organisations, health and social services, and private businesses. The iterative engagement process that organically emerged in Phase 1 continued into Phase 2, leading to outputs that were highly valued by many stakeholders. For example, critical infrastructure companies picked up some of the disaster risk information outputs generated by AF8, for use in their modelling of loss-of-service interdependencies and network resiliency design. AF8 researchers brought in doctoral research students to examine additional requested high-priority topics in depth, such as sub-regional network analysis for critical

infrastructure (see Davies, 2019). These outputs, created during the engagement process used in Phase 1, were also well received during District Council planning sessions, such as the one which took place within the Canterbury region on 31 August 2017 (see Figure 4.1). Valued resources provided by AF8 were disaster risk information and maps relating to impacts to communities and critical infrastructure over time. These fed directly into community response plans for parts of the District, as well as Police response plans for an AF event, demonstrating direct practice and policy uptake of the disaster risk information generated by AF8.

However, it became apparent in Phase 2 that relying on an ad-hoc informal engagement process did not allow for the flexibility needed to scale up and engage with a much wider range of stakeholders. When, for example, an external scientific group was tasked with modelling casualty numbers, the results were not fit for AF8 purposes due to inherent limitations in the base model which required large assumptions, scaling of international data and models to the New Zealand context, and a lack of adequate data for input. On October 2017 (see Figure 4.1), a workshop involving core AF8 scientists and the Steering Group conducted an expert judgement exercise to develop an appropriate approach for assessing potential casualties. This resulted in a co-created disaster risk assessment methodology and knowledge, marking an important point in the evolution of the AF8 engagement process. While iterative engagement from either side of the interface between scientists and practitioners was reasonably effective for some parts of the scenario development process, this new approach allowed the collaboration to be more adaptive, scaling up engagement as needed to allow for a more time- and resource-intensive co-creation. Phase 2 ended in October 2018 with the publication of the SAFER Framework.

At that point, Phase 3 began, using the co-created outputs from Phases 1 and 2 for outreach through public education campaigns (such as the 'AF8 Roadshow') and presentations to potential stakeholders. These occurred at the local, regional, and national levels, and were aimed at public, private, and government organisations. A June 2019 report published by AF8 describes over 150 presentations given to a cumulative audience of around 8,000, and reports more than 24,000 website views (Project AF8, 2019). Additionally, over 1,100 students in secondary school are reported to have participated in AF8 related activities designed to educate and engage on the risks to an AF event (Project AF8, 2019). The success of Phase 3 is indicated by continued public appetite for AF8 outputs, as demonstrated by multiple community group

and organisation requests for presentations regarding AF hazards, impacts, and disaster planning.

The outreach style of Phase 3 was also collaborative, with both AF8 scientists and practitioners agreeing that joint presentations were necessary to increase understanding of AF8 outputs, and therefore increase likely uptake of the disaster risk information by the wider public. An interviewed practitioner explains the benefits of this approach:

> The best thing that the community can see, is a scientist standing beside a practitioner, saying 'we believe that this is what's going to happen from a science perspective,' and the practitioner saying, 'and understanding that, this is how we intend to deal with it,' because that gives people confidence.

These co-delivered presentations provided credibility to practitioner messaging in the eyes of the audience. As one practitioner put it:

> It gives us a bit of robustness in our discussions with the wider stakeholders that it is not just scaremongering – there is actually some thought behind what we are talking about.

All were agreed that a substantial challenge in Phase 3 was to ensure that stakeholders understood enough about the risk to stimulate risk mitigation activity, but were not made to feel fatalistic due to the severity of a potential AF rupture. It was necessary to find an appropriate balance between presenting the extent of the natural earthquake processes, the range of likely consequent impacts, and what that would be likely to mean for stakeholders. AF8 presenters address this issue by devoting substantial outreach time to group discussions, and by providing ample opportunities for audience questions. For example AF8 outputs were requested by a District Council to aid in their emergency response planning and policy-making. In August 2017, a full day of Council activities were devoted to a planning exercise focused on earthquake response, of which the majority consisted of presentations and discussions led by AF8 team members. Raw data and AF hazard maps were presented initially creating apparent shock amongst the audience. However, the likely consequences of such an event were then contextualised, through directed discussion and regional impact maps, allowing Council staff to benchmark likely impacts to better-known hazards and risks. Of particular popularity within the provided handouts were maps showing the effect of earthquake shaking on specific infrastructure elements (such as rail, power, water mains, sewerage pipes, storm surge drains, and water races).

At the national level, multiple government agencies have approached AF8 seeking to become end-users of their co-created disaster risk information outputs. One example is an agency which experienced disruptive impacts to its infrastructure as a direct result of the 2010 – 2011 Canterbury Earthquake Sequence, resulting in logistical and security issues. Bespoke disaster risk information produced by AF8 incorporated data provided by the agency, and results were assimilated by their in-house emergency planners.

4.6.2.2. November 2016 earthquake and raising of AF8 profile

This success and appetite for AF8 outputs may be attributed, in part, to the effect of the Mw 7.8 Kaikōura earthquake on 14 November 2016. This event broadly ruptured from south to north along 180 km of fault line on the northeast coast of the South Island, sending seismic waves northwards towards Wellington, and prompting the evacuation and closure of 11% of office buildings in this capital city of New Zealand (Bradley et al., 2017). There are broad similarities between the South Island experiences following the Kaikōura earthquake and what is anticipated as likely following a large AF rupture. While an AF8 scenario would be larger in scale and extent (generating twice as much energy and ~60% more shaking), the social, environmental, and infrastructure impacts predicted are expected to be comparable to those of the Kaikōura earthquake. Focus group participants (in May 2018) agreed that this event was likely to have increased the appetite for AF8 outputs. One participant commented:

> The thing that really made Project AF8 work, I think, is that in November of that year we had the Kaikōura quake. (…) It was a bit of a smaller event but it actually reinforced all the stuff that we had been talking about: the landslips, the earth rupture, and all that seismic stuff. So, we had this massive real test of the scenario and since then there has been this willingness to make some progress in this area. I think the events have really helped us make this a more collaborative approach.

Given the renewed public interest in earthquake risk reduction following the Kaikōura earthquake, AF8 is "now working quite well for current political discourse," according to one participant, and enjoys continued support as proof of New Zealand's proactive stance on future earthquake risk reduction.

4.7. Discussion

At its core, both the knowledge generated through the AF8 initiative and the process by which scientists and stakeholders interfaced aimed to find an equilibrium between the credibility offered by evidence-based disaster risk science and its relevance for DRM practice. This balance is required to enhance the legitimacy of both co-production processes and coproduced knowledge (Fearnley and Beaven, 2018). The following discussion focuses on the AF8 engagement process. Preferred risk metrics and acceptable levels of uncertainty are explored in terms of practitioner needs and uses. Key moments in the evolution of the AF8 engagement process are considered, as well as the implications for disaster risk information content.

4.7.1. Risk metrics and uncertainty

As the results show, practitioners wanted to understand the operational implications of an AF rupture and disaster. For this to happen, disaster risk information needed to include interdependencies between systems and multi-hazard perspectives, and to be sensitive to dynamic changes in the disaster response system following mitigation decisions. Interviewed practitioners requested risk metrics that quantified disaster impacts and implications for the human system, rather than information which simply characterised the natural hazard. The recognition of specific informational needs for earthquake response and recovery in the rural context was enhanced by the Kaikōura earthquake, which provided insight into some of the challenges likely faced by emergency managers after an AF rupture, given the rural nature of New Zealand's South Island.

4.7.1.1. Preferred risk metrics

To aid in pre-event planning, interviewed practitioners and policy makers requested disaster risk information on hazard impacts to humans and society, specifically the built environment, as well as anything that could affect response logistics. Research which considered human-centric impacts for use in DRM planning and which modelled the logistical considerations of a disaster response (especially over time) were found to be useful for all

practitioners. However, other kinds of information were more specific to practitioner needs at different times and at different stages within the pre-event planning phase.

At the outset of AF8, a lack of clarity on the needs, uses, and options available contributed to challenges in choosing risk metrics (i.e. what to measure) for use in AF8 outputs. A complex and multi-faceted tension between scientists and practitioners revealed confusion regarding the disaster risk knowledge (1) initially provided by scientists, (2) able to be provided by scientists, and (3) that would be relevant to practitioner needs (Figure 4.3). The co-creation process was used to address these issues.

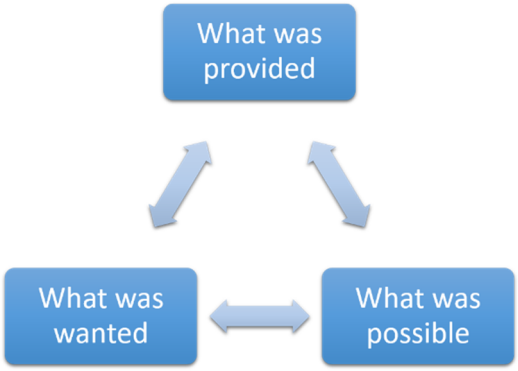

Figure 4.3 Conceptual diagram showing core sources of tension regarding disaster risk information content at outset of Project AF8.

4.7.1.2. Uncertainty in disaster risk information

A challenge faced by AF8 was that scientists and practitioners never formally came to an agreement on what constituted an acceptable level of uncertainty for disaster risk information outputs. Casualty modelling was an example, where initial disaster risk modelling provided to AF8 did not meet a sufficient threshold for acceptable uncertainty. Despite this, there was a high appetite among interviewed practitioners for disaster risk information regarding sensitive topics such as casualties and death, even though all agreed that this information could be highly uncertain. The support and context needed for sharing uncertain outputs of this kind was provided by the intensive co-creation process used during the casualty modelling workshop (Figure 4.1). Experiences with AF8 showed that this is where co-creation methods are essential (see also Cvitanovic et al., 2015). Once contextualisation of the model outputs was provided, and enough face-to-face interaction between the scientists and practitioners occurred, only then were practitioners able to understand the modelling limitations and trust the information. The

co-creation environment was likely to have been responsible for effecting that change. One of the big lessons from AF8 was that having a strong relationship between scientific modellers and practitioners (with other perspectives feeding in) was crucial to ensuring that disaster risk information was scientifically adequate and fit for use in practice within the New Zealand context.

The practitioners and policy makers who participated in this study were flexible when it came to coping with high uncertainty in disaster risk information, which indicates that they expect to rely largely on their own expert judgment when applying information in any given context. Possibly reflecting the need to stay open to potentially crucial information, interviewees used vague and conditional wording to describe desired disaster risk information. This meant that in the AF8 process, scientists were required to use their own judgment to identify what they believed stakeholders would want. It is likely that clearer coproduction parameters co-created by practitioners and scientists would have increased the efficiency and efficacy of the science-practice-policy AF8 interface, especially during the early project design phases (Wyborn et al., 2017; Wyborn et al., 2019). At the same time, it is neither feasible nor necessary for practitioners to be involved in every aspect of scientific decision making (Lemos et al., 2018). A clear formal co-creation structure and function devised collaboratively at the outset would have provided for the most effective balance here. In the absence of such structures, it has been well established that stakeholders and scientists struggle to agree on acceptable levels of uncertainty (Endter-Wada et al., 1998; Sarkki et al., 2014; Cvitanovic et al., 2015). In the case of AF8, the engagement process and subsequent co-creation managed this most of the time, but inefficiencies and the possibility of missed opportunities persisted. Ultimately, it is clear that understanding of disaster risk uncertainty is substantially improved when scientists, stakeholders, and other end-users discuss it face-to-face (Bradley et al., 2016; Fearnley and Beaven, 2018; Doyle et al., 2019).

4.7.2. Evolving co-creation process

The management of the AF8 science-practice boundary evolved over time. The first AF8 workshop established an initial collaborative approach that relied on ad-hoc discussions on either side of this interface, and iterated from one side to the other. This informal early

process was required to evolve into activities that brought either side of this interface together to respond to the greater complexity and demands of Phase 2 collaboration.

4.7.2.1. The importance of the initial workshop

The initial workshop was the foundation of all future AF8 engagement. It is useful to think of the output of this workshop, an AF rupture scenario, as a boundary object as defined by Star (2010). Shared by several different groups (e.g. scientists, emergency management practitioners, policy- and decision-makers, and community groups or other stakeholders), this scenario helped to focus discussions, and the exploration of options between these communities (Impedovo and Manuti, 2016). The AF8 co-creation process centred on this boundary object, but in the absence of transparent formally structured processes it developed in an organic informal way that gave rise to initial tensions as to how the interface between scientists and practitioners would be managed. A collaboratively agreed structure and processes would have facilitated the stronger direction from practitioners that was required in this early workshop, by including them in the debates that were occurring between scientists. With a clearer understanding of what was needed by practitioners, and what constituted an acceptable level of uncertainty for them, scientists could have provided practitioners with a better understanding of research methods and hazard modelling possibilities. A lesson for both sides of the research-practice interface at this workshop was that ad hoc collaborations can take longer to achieve the required compromise and adaptability required of co-creation than initiatives that collaboratively develop and agree on co-creation processes and objectives at the outset.

Following the workshop, Steering Group practitioners needed early work from scientists to inform their professional timetables. It has been well established that the rapid needs of practitioners coupled with the comparatively time-consuming processes required to develop scientifically credible information can result in tension (Cash et al., 2003; Parker and Crona, 2012; Sarkki et al., 2014; Beaven et al., 2017). Scientists typically work largely autonomously, and increasingly within multi-year funding mechanisms that contribute a degree of freedom to prioritise topics as required, but add to overall workloads. Senior research scientists involved in the AF8 scenario development for example were managing multiple priorities, due to involvement in a number of parallel projects, which added to the time required for further scenario development. This fundamental temporal boundary tension contributed to practitioner

frustration and risked eroding trust with scientists in the early stages. It was exacerbated by the hierarchical AF8 formal structure which required the lone scientist on the Steering Group to access and provide all science inputs to the Steering Group from the wider scientific community involved. A more balanced, transparent, and collaboratively developed co-creation structure that included more scientists on the Steering Group would have had the potential to reduce the time required to access scientific knowledge, and to enhance understanding among both scientists and practitioners. Such a structure applied across the larger AF8 collaboration would have had the potential to bring scientists and practitioners together to design research programmes over longer time periods, providing the opportunity to have poorly understand hazard science addressed in depth, gaining knowledge which is otherwise difficult to achieve within the strict budgetary and temporal constraints on DRM practitioner commitments.

4.7.2.2. Outreach enhanced by co-creation

Again, having both a scientist and practitioner present the outputs and learnings of AF8 to stakeholders enhanced the legitimacy of the work and the value of public messaging. The scientist was able to explain the underlying research and limitations of the AF8 modelling (i.e. enhancing credibility), and the practitioner was then able to use evidence-based research to support their messaging (i.e. enhancing relevance). The legitimacy of these co-delivered presentations was only possible because the AF8 process had evolved from iterative consultation (i.e. back-and-forth engagement) into co-creation (Figure 4.4) (Cash et al., 2002; Fearnley and Beaven, 2018). The research informing the AF8 scenario is highly technical and very complex, making it difficult to present for anyone lacking the relevant research expertise. The success of having both a scientist and practitioner present outputs together to stakeholders highlights the importance of getting the right people in the right room at the right time. This proved ideal for multiple presentation formats, from presentations to technical panels all the way to public presentations at secondary schools.

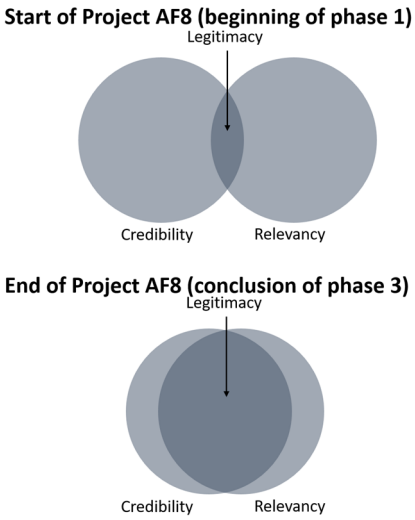

Figure 4.4 Conceptual diagram of relative changes over time to credibility, relevancy, and legitimacy of Project AF8, brought about by the process used to co-create disaster risk information and presentation outputs (adapted from Fearnley and Beaven, 2018).

Overall, although the transition from the initial workshop to the more co-creative processes developed in Phases 2 and 3 (Figure 4.2) was difficult and highly complex, it ultimately produced outcomes of value for practitioners, scientists and communities. Early difficulties were consistent with issues identified in international literature concerning coproduction, and the need for transparent formal collaborative processes to manage the sort of decision making required by complex issues like disaster risk management (Beaven et al., 2017; Wyborn et al., 2017; Wyborn et al., 2019). As the co-creation process evolved and became more integrated, the benefits and the value of more collective approaches to complex issues of this kind became increasingly apparent.

4.8. Conclusion

The AF8 initiative was tailored to the specific hazards and political, natural, and social environments in rural and urban South Island settings, highlighting the way that the complexities of DRM decision making can play out in New Zealand. A degree of collaboration is mandated by the CDEM Act 2002 (New Zealand Legislation, 2019b), which has facilitated a collaborative culture within the CDEM sector and critical infrastructure groups (MCDEM, 2017b). It is likely that this culture contributed to the high initial levels of AF8 engagement from these sectors, resulting in early gains in making disaster risk knowledge more relevant to their needs (such as loss-of-service maps). This early progress contributed in turn to demand

from other sectors (such as insurance, additional government agencies, schools, and community groups) to be involved in the AF8 initiative. The key was the collaborative development of the knowledge and outputs required to achieve desired outcomes (such as the development of impact maps rather than hazard maps, and the need to include impact modelling over time). This co-created research incorporated the operational implications of future disasters, making it of higher value to practitioners and policy makers for pre-event planning purposes. The modelling of highly sensitive issues, such as casualty estimates, were of particularly high value to practitioners, although scientists and practitioners remained deeply concerned about the appropriate application of these estimates. Direct and on-going stakeholder involvement in the modelled outputs (whether for communities or expert organisations) incrementally generated growing trust in and uptake of the disaster risk knowledge generated through AF8. Combining scientific and stakeholder knowledge also ensured that the limitations of both modelling and data were carefully communicated and fully contextualised, so that both scientists and decision makers were able to apply them appropriately.

Understanding what practitioners consider to be an acceptable level of uncertainty for disaster risk information content remained a challenge. Determining the threshold was not an explicit AF8 goal. However, it was necessary in order to identify the point at which disaster risk information became 'good enough' for practitioners. The AF8 practitioners necessarily relied on qualitative judgment and their own disciplinary, organisational, and cultural expertise to determine this threshold. The key to enabling informed practitioner and policy maker decisions was the co-creation environment, characterised by mutual trust and respect, in which interactions between scientists and stakeholders contributed to the shared knowledge of likely disaster impacts required to ensure that research findings addressed stakeholder needs, and that decision-making was informed by credible science.

This study also offered insights into AF8 collaboration, co-creation, and engagement processes. This big interdisciplinary, cross-sector project provided a forum for sustained dialogue between scientists and practitioners, generating mutual understanding of professional needs and limitations on both sides of the science-practice boundary. Participating practitioners obtained a better understanding of the lengthy research time frames, funding cycles, peer-review processes, and publication needs of scientists. Conversely, scientists were exposed to the professional requirements of practitioners, their need to work within an environment characterised by uncertainty, and within a relatively rapid time frame. A key finding in this

context was the need for a transparent, collaboratively designed co-creation structure at the outset of the AF8 initiative. Without a formal structure, AF8 had to develop workarounds, and ultimately success relied heavily on informal leadership and the high levels of trust and goodwill that already existed between members.

The lack of an explicit co-creation structure left the multi-hazard impact scenario as the nexus at the centre pulling diverse aspects of the co-creation process together. The multi-hazard impact focus of the scenario allowed for the wide variety of actors involved to feed into different aspects of the scenario, thereby promoting a scenario-building process that included multiple stakeholders.

Ultimately the broad lessons from the AF8 engagement process add weight to findings in other topic areas concerning the co-production of knowledge and decision-making. The value of the AF8 initiative relied as much on the co-creation process that evolved over time as it did on the knowledge and outputs that it produced. Balancing the influence and needs of the stakeholder and research communities involved was the key to enhancing the legitimacy of AF8 processes and outputs. This was equally evident in the outreach phase, where knowledge sharing was enhanced when researchers and practitioners workshopped AF8 knowledge with communities. These lessons are supported by a high level of documentation on the internal structure and engagement processes used by the initiative, in particular through yearly progress reports and peer-reviewed articles. This level of transparency seems to be high in comparison with other disaster risk management initiatives in New Zealand, facilitating the evaluation of AF8 in this respect, though further work exploring the specific differences and methods used in these various initiatives is needed. The lessons from AF8 are likely to be of value to those initiating other large interdisciplinary initiatives centred around the research-practice interface, particularly those dealing with disaster risk reduction and emergency management.

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Chapter Five – Conclusion

5.1. Summary

The underlying drivers of rural disaster risk are complex (UNDRR, 2009; OECD, 2012; World Bank, 2013; GFDRR, 2016; Oliver-Smith, 2016). Effective disaster risk management (DRM) therefore relies on the inclusion of multiple perspectives and knowledge systems (Scolobig et al., 2015). This is particularly true for managing rural disaster risk, which has been shown to have specific needs before, during, and after a disaster (Wall and Marzall, 2006; World Bank, 2006; Eakin et al., 2008; Boon, 2014; De et al., 2014; Cradock-Henry et al., 2018; Fang et al., 2018; McKay et al., 2019). This thesis contributes to a greater understanding of the vulnerabilities and capacities of rural regions in high-income nations to disasters. It strengthens the empirical evidence base on the impacts caused by rural disasters in a high-income nation context, which in turn enables more informed decision-making for future rural disaster planning and response efforts in high-income nations. Conclusions to this thesis are drawn from the chapter findings. The following three sections reflect each research objective identified in Chapter 1. Firstly, the key drivers of disaster risk in rural New Zealand are identified. Secondly, the institutional and social structures and environments that inform, enable, and constrain DRM decision-making in rural New Zealand are mapped. Thirdly, opportunities to enhance the effectiveness of DRM in rural New Zealand are described. Next, limitations and challenges to the thesis and research methodology are discussed. This chapter ends with an exploration of opportunities for future research.

5.2. Broad drivers of disaster risk in rural New Zealand

Levels of disaster risk vary when its underlying components (hazard, exposure, and vulnerability) are subject to change (IPCC, 2012; GFDRR, 2016). This thesis finds that, in the rural New Zealand context, the key drivers of disaster risk stem predominantly from interconnected aspects of the natural, social, and economic environments. The natural environment in New Zealand is characterised by an active tectonic boundary, and subject to both arctic and equatorial weather patterns, resulting in a nation sensitive to the effects of climate change and highly exposed to multiple and potentially overlapping natural hazards

(MCDEM, 2007a). Socially, changing demographics are affecting the make-up of rural society (Smith et al., 2011), with implications for disaster resilience and the effectiveness of existing DRM methods to enhance it (Wisner et al., 2004; GFDRR, 2016). The economic health of rural businesses, the wider rural sector, and New Zealand as a whole, contribute directly to levels of rural disaster risk (Patterson et al., 2006; Stroombergen et al., 2006; Cradock-Henry, 2017; Spector et al., 2019). Additionally, an evolving and increasingly technological rural economy has become ever more reliant on vulnerable distributed infrastructure (e.g. transportation, telecommunications, and electric supply networks), as economic activities based in rural areas (e.g. agriculture, animal husbandry, and tourism flow) rely on increasingly long value chains that can easily be broken (MCDEM, 2007a; Ye and Abe, 2012). A detailed description follows on each of these aspects, how they interrelate, and the ways in which they feature in the two thesis case studies.

5.2.1. Geographic factors

New Zealand is an island nation whose landscape has been shaped by active tectonic plates, volcanoes, and glaciers over millions of years, resulting in uniquely evolved ecosystems (MCDEM, 2007a). This highly complex and dynamic landscape is coupled with the mid-latitude zone of westerly winds in the Southern Hemisphere known as the ‘roaring forties’ (MCDEM, 2007a). New Zealand is therefore exposed to a multi-hazard environment, made worse by the ongoing effects of climate change (MCDEM, 2007a). The overlap of an earthquake and a three-year drought within the North Canterbury region (Chapters 2 and 3) is evidence of this.

The 2016 Kaikōura earthquake case study used in the thesis finds that the natural environment was a key contributor to, and driver of, rural disaster risk. For example, the hilly terrain of the rural regions closest to the 2016 Kaikōura earthquake epicentre resulted in thousands of co-seismic landslides, blocking roads, damming waterways, damaging fencing and other on-farm infrastructure (e.g. dairy milking sheds), which resulted in complex and compounding impacts to rural value chains. Co-seismic landsliding was a major contributor to disaster risk following the Kaikōura earthquake largely due to the lack of access it created in to, out of, and within rural areas. Thesis findings support other work that has shown how these geographic factors halted tourism flows in and across the region (Simmons, 2017), and

contributed to nuanced implications for farms and agribusinesses (Stevenson et al., 2017). For example, thesis interview participants described how farm products could not be moved to market due to damaged transportation infrastructure. While this isolation was largely driven by geographic factors, the resulting break in rural value chains had important economic consequences, discussed in Section 5.2.3.

Furthermore, thesis results find that the pre-existing North Canterbury drought had forced many farmers to rely on incoming deliveries of water and livestock feed from outside the region (Chapter 2). The access issues caused by the co-seismic landsliding meant that isolated farmers had fewer methods to lessen the regional impacts of the drought, and were therefore forced to simultaneously manage impacts from both the earthquake and the drought on their own. In this sense, the multi-hazard context increased the risk of disaster in the area. Fortunately, approximately three years of regional drought response efforts were beneficial to the Kaikōura earthquake response. Results show that while many rural North Canterbury residents were emotionally and financially stressed by the adverse effects of the on-going drought, reducing their capacity to manage the additional and compounded impacts of the earthquake, previous collective efforts to manage drought impacts had resulted in the development of networks and relationships that proved essential in the early phase of the earthquake response. These social factors affecting disaster risk are discussed in a later section.

The important contribution of geographical context to levels of disaster risk can further be highlighted using a comparison with the 2010 Darfield earthquake. Similarly to the 2016 Kaikōura earthquake, the Darfield earthquake occurred in rural Canterbury (Whitman et al., 2013). However, unlike the hilly context in which the Kaikōura earthquake originated, the Darfield earthquake took place on primarily flat glacio-pluvial plains (Potter et al., 2015; Quigley et al., 2016), where low exposure to co-seismic landslides was associated with much less of the type of disruption seen after the Kaikōura earthquake. The different geographical settings of these two rural earthquakes in the same Canterbury region demonstrates how geographic context can directly influence and contribute to levels of disaster risk.

5.2.2. Social factors

Social and demographic shifts within New Zealand's rural regions, including those brought about by urbanisation and general population growth, have resulted in major changes

to the composition of rural society (Rutledge et al., 2010; Smith et al., 2011; Statistics New Zealand, 2013; Cradock-Henry, 2017). This, in turn, fundamentally changes the existing disaster response capacities of rural populations, as well as the issues that rural DRM may need to address and plan for during an emergency (Cradock-Henry, 2017). Chapter 2 details the make-up of rural properties in North Canterbury when the 2016 Kaikōura earthquake occurred. Results from a geospatial analysis show that 53.2% of the rural properties that were subjected to ground shaking considered 'largely observed' (i.e. values of 4 and above on the Modified Mercalli Intensity scale) (GNS, 2020) were hobby farm owners, commonly referred to as 'lifestyle blocks' in New Zealand. Lifestyle blocks may serve as personal recreational land, can generate small amounts of income through leisure farming, or function as a country home (Fairweather and Robertson, 2000; Sanson et al., 2004). Lifestyle block owners therefore have varying capacities, resources, and equipment able to respond to the impacts of natural hazards, and therefore can have very different priorities and needs during a disaster as compared to other rural residents such as farmers (Fairweather and Robertson, 2000; OECD, 2012; Andrew and Dymond, 2013). Thesis findings suggest that the varied demographic make-up of rural society in North Canterbury (which, along with lifestyle bock owners, includes vulnerable populations such as the elderly, youth, disabled, and migrant farm workers) in turn generates a variety of vulnerabilities that must be reflected in the planning needs and response priorities of rural DRM.

This shift in demographic make-up of rural populations also brings about changes to existing rural social and organisational networks, which has been shown to affect levels of local disaster risk (Hawkins et al., 2010; Minamoto, 2010; Aldrich, 2011; LaLone, 2012; Islam and Walkerden, 2014; Islam and Walkerden, 2015). Both the 2016 Kaikōura earthquake (Chapters 2 and 3) and Project AF8 (Chapter 4) case studies showed the value in having both established and emergent rural organisations, and strong networks between them, to enhance response and recovery to disasters. For example, following the Kaikōura earthquake North Canterbury's pre-existing Drought Committee (later re-branded as the Earthquake Committee) was vital in enabling response aid to the earthquake, and helpful in providing situational awareness both ways between some rural resident groups and the official government response operation. While other work has shown the value of similar networks and organisations in the Kaikōura township setting (Cradock-Henry et al., 2019), the newly established organisations which emerged following the earthquake to strengthen rural networks, such as 'TeamAg,' were

informed by the wider experiences specific to the rural sector, which had been through big climactic events and biosecurity events (e.g. Mycoplasma bovis) over the last ten years.

In addition to organisational networks, Chapters 2 and 3 also showed that peer-to-peer relationships between rural inhabitants helped provide support to residents following the Kaikōura earthquake. Therefore, demographic and other changes to social contexts within rural regions could result in neighbours unfamiliar with each other, which would impede the type of potential peer-to-peer networks this thesis confirms as useful in reducing disaster risk.

5.2.3. Economic factors

In order to keep pace with these demographic changes to the make-up of rural society (such as population growth), economies are changing, as global efforts to increase productivity in rural areas (especially in high-income nations) have resulted in the human modification of the natural environment and the use of intensive farming techniques and strategies to maximise resources and realise additional yields (Keating and McCown, 2001; De Clercq et al., 2018). Accordingly, the Kaikōura earthquake case study findings showed a need for specialist attention to repair technologically advanced dairy milking sheds and to fix precision irrigation systems that had been distorted due to ground movement in North Canterbury (Chapter 2). Thesis results show this was not possible immediately following the earthquake, with some farms reportedly unable to continue normal business operations due to disruptions in the transportation infrastructure caused by co-seismic landsliding. The resulting isolation was found to directly impact local economies in North Canterbury, as these resulted in cuts to rural value chains, breaks in business continuity, and displaced tourists and residents. This thesis supports both international academic studies (Leichenko and O'Brien, 2002; Anderson, 2003; Ye and Abe, 2012) and New Zealand government reports (MCDEM, 2007a; New Zealand Government, 2015) that suggest rural economic reliance on increasingly long, distributed infrastructure networks across large distances is increasing rural exposure and vulnerability to a range of natural hazards.

Insights on other economic factors that can drive rural disaster risk following an earthquake in North Canterbury can be highlighted through the different economic contexts in which the 2010 Darfield and 2016 Kaikōura earthquakes occurred. Studies on the economic impact of the 2010 Darfield earthquake showed that while some farms and rural businesses

were badly affected by the earthquake (Glassey and Wilson, 2011), most capital losses were able to be covered through a combination of private financial reserves, insurance, government aid, as well as strong commodity prices and the ability to quickly sell goods at a favourable market rate (Parker and Steenkamp, 2012; Doyle and Noy, 2013; Whitman et al., 2013; Potter et al., 2015). However, Chapters 2 and 3 show how the 2016 Kaikōura earthquake occurred in a very different economic context. Thesis findings confirm that the Kaikōura earthquake caused financial hardships for livelihoods related to both the tourism industry (given interrupted tourism flows) and for those involved in the primary industries (due to a multi-hazard context). Findings indicate that farmers and others with eco-system based livelihoods in North Canterbury were already operating within a highly pre-stressed natural and financial environment due to the impacts of the pre-existing drought, and were not well placed to address the additional negative impacts of the earthquake. For example, thesis interviews reveal that many local businesses and individuals had reportedly used up much, if not all, of their financial reserves combatting three years of continued drought conditions, and were therefore unable to draw on similar personal financial reserves (or exhausted bank loans) to manage the consequences brought about by the subsequent earthquake impacts. Despite vital assistance provided by large private agribusiness companies highly active in the aftermath of the earthquake (such as DairyNZ, Fonterra, and Beef and Lamb), this event was still considered economically disruptive, if not catastrophic, for regional residents and impacted agribusinesses (Stevenson et al., 2017; Cradock-Henry and Fountain, 2019).

The Kaikōura earthquake case study also suggests that economic drivers of disaster risk in New Zealand can vary depending on the scale and perspective taken (Chapters 2 and 3). Results indicate that economic factors driving disaster risk at the local level (directly impacting individuals and small businesses) were different from the economic factors of direct concern to central government decision-makers. For example, thesis interviews confirm that rural areas in North Canterbury suffered both direct losses (including destroyed crops, livestock, and personal property) and indirect losses (through severed value chains and disruptions to business continuity) as a result of this earthquake. These results align with findings from MacDonald et al. (2017) who show how the transportation of goods, business operability, and tourism flows into and out of the North Canterbury region were all negatively affected by this earthquake. While the severity of earthquake impacts were high at local and rural levels, other work has shown that these impacts were largely localised and less severe at the national level (Simmons,

2017; Stevenson et al., 2017; Cradock-Henry and Fountain, 2019). For example, Simmons (2017) found that while tourism flow patterns shifted to avoid the region affected by the earthquake, the overall number of tourists within New Zealand stayed essentially the same. Cradock-Henry and Fountain (2019) found similar results, showing that while some wineries experienced reduced visitor numbers following the earthquake, others benefitted from this change in tourism flow. In other words, while tourists did not necessarily contribute to the North Canterbury economy, they still ultimately contributed to the national economy.

One of the key thesis findings relating to drivers of disaster risk in rural New Zealand relates directly to how consistently and systematically rural North Canterbury interview participants described the on-going drought as being a greater disaster, from their perspective, when compared with the Kaikōura earthquake. Results from this case study (Chapters 2 and 3) show that the medium to long-term financial impacts and the indirect consequences of the multi-hazard context (such as the implications to overall farm health and business continuity) were more important to address in the early response to the earthquake as compared with the immediate physical needs that are typically the focus of traditional emergency response (such as food, water, and shelter). In this case study context, findings suggest that human welfare needs were not an essential requirement of the primary response for many rural populations. However, future rural disasters in New Zealand may very well require an emphasis be placed on human welfare, depending on the context. Therefore, this thesis highlights the importance of timely and robust needs assessments and impact assessments following an earthquake to correctly determine the response priorities of affected rural areas, so that the local response is appropriate for the rural context. To ensure effective DRM and risk reduction in rural areas, this rural context (including the local variations therein), should actively inform any disaster response mechanism, and ideally be integrated into future rural DRM planning.

5.3. Factors that inform, enable, and constrain DRM decision-making in rural New Zealand

This thesis identified and mapped some of the actors, and the social and institutional factors, that contributed to enabling, inhibiting, and informing DRM decision-making and implementation in two rural case studies. It reveals a highly complex web of individuals, private businesses, communities, public sector organisations, and government agencies active in this

space. Some were based full-time in rural areas while others were based in urban areas, but operate in rural areas when necessary. The thesis case studies show that the DRM roles and responsibilities of these actors at times overlapped and interlinked, and elsewhere contributed to gaps. In addition, some structures, such as the national legislation pertaining to disaster risk reduction, were found to both enable rural DRM in certain ways while inhibit it in others. This thesis finds that the main influences on DRM decision-making in rural New Zealand appear to be: social and human capital, legislation, government agency structures and response coordination, and economic capital. Acknowledging each of these factors, the following paragraphs summarise the varying degrees in which they may inform, enable, and inhibit rural DRM.

High levels of human and social capital found in both thesis case studies highlight aspects of rural society that can inform and enable rural DRM in the New Zealand context. A large number and variety of rural organisations were involved in local response and recovery efforts following the Kaikōura earthquake (Chapter 3). The networks and committees formed locally during the preceding three years of drought, originally aimed at increasing local drought resilience, had the additional effect of enhancing local earthquake resilience. Pre-existing community connections (both formal and informal) as well as committees (such as the Drought Committee) offered important networks that were found to facilitate and benefit rural DRM in the context of the case study.

In the second case study used by this thesis, Project AF8 brought together multiple organisations and communities (i.e. human capital) to collaboratively identify and develop evidence-based, multi-sectoral, and cross-jurisdictionally coordinated response plans with the aim of increasing disaster resilience to earthquakes across the South Island of New Zealand. While not explicitly focused on the rural context, given that most of the South Island is rural, Project AF8 therefore implicitly addresses DRM issues for rural New Zealand. The co-creation of scientific knowledge, and of government response plans, in preparation for an Alpine Fault earthquake was found to have enabled more effective DRM decision-making by including local knowledge and recommendations specific to rural contexts (Chapter 4).

Another factor affecting DRM decision-making in New Zealand is the national DRM legislation, internationally recognised as being one of the best in the world (IFRC, 2014). However, this legislative environment remains highly complex and was found to both enable and constrain aspects of rural DRM (Chapters 3 and 4). The legislative framework that guides

strategies, plans, policies, codes, and practices supporting DRM and risk reduction decision-making outcomes are spread across the following acts (NEMA, 2016; NEMA, 2020a):

- Biosecurity Act 1993
- Building Act 2004 and Building Code
- Civil Defence Emergency Management Act 2002
- Defence Act 1990
- Earthquake Commission Act 1993
- Epidemic Preparedness Act 2006
- Fire and Emergency New Zealand Act 2017
- Greater Christchurch Regeneration Act 2016
- Hazardous Substances and New Organisms Act 1996
- Health Act 1956
- Health and Safety at Work Act 2015
- International Terrorism Act 1987
- Local Government Act 2002
- Maritime Transport Act 1994
- Public Works Act 1981
- Resource Management Act 1991
- Soil Conservation and Rivers Control Act 1941

Much of this legislation reflects a policy of partial decentralisation, in which New Zealand's central government has actively promoted the devolution of DRM from national to regional and local levels, as per the vision of "communities understanding and managing their hazards" (NEMA, 2016). This means that aspects of the various Acts are implemented by each of the 78 local authorities representing all areas of New Zealand. These authorities include 11 Regional Councils, 54 District Councils, and 13 City Councils (which are largely urban, such as the Auckland Council), resulting in a complex web of legislative and government authorities. While not every piece of legislation, nor every local authority, applies to the rural context, these structures can both enable (through guidance) and inhibit (through misinterpretations and complexity) rural DRM.

Other research has suggested that New Zealand currently lacks an effective and broad cross-sector DRM coordination platform, as recommended in the Sendai Framework for Disaster Risk Reduction 2015 – 2030 (SFDRR), to coordinate the efforts informed by this

complex mix of legislation and agency responsibilities, at national, regional, and district levels (UNDRR, 2015; Basher, 2016). Without such functioning coordination mechanisms, government agencies responding to a disaster can interpret their own and others' mandates in different ways, as seen in both thesis case studies, reducing the effectiveness of DRM. For example, following the Kaikōura earthquake Civil Defence and Emergency Management (CDEM) (the agency mandated to lead the government response) assumed the Ministry for Primary Industries (MPI) would coordinate rural sector organisations during the earthquake response, and act as a conduit for communicating rural needs and issues into the government response mechanism (Chapter 3). However, MPI saw their role as a "supporter" not a "leader" of local response efforts. These differences in assumed roles and responsibilities to disaster response reflect limited coordination between CDEM, MPI, and other responding agencies. This thesis agrees with Basher (2016) that current governance arrangements in New Zealand do not include a robust and accountable platform to coordinate disaster risk reduction and DRM efforts.

This legislative environment contributed to largely distinct efforts by these two key responding agencies, focused on two interacting and overlapping disasters: the Kaikōura earthquake and a North Canterbury drought. While CDEM led the Kaikōura earthquake response efforts, it was not involved in the preceding regional drought response, which had been the legislative responsibility of MPI. The multi-season drought in the rural North Canterbury region resulted in MPI's establishment of networks, organisational arrangements, and relationships across the region in the three years leading up to the earthquake (Chapter 3). Had CDEM and MPI been better integrated, CDEM may have been able to more quickly and more effectively use MPI's established networks to enhance their own earthquake response arrangements.

The Kaikōura earthquake case study also revealed a lack of horizontal integration of organisations within the rural sector, within the responding government agencies, and between both these groups (Chapters 2 and 3). Vertical integration between local, regional, and national level responses was also found to be lacking. The cross-agency 'whole of society' coordination platforms for disaster risk reduction proposed in the SFDRR would have the potential to address both these issues. Integrating agencies, private sector, and community actors at national, regional, and local levels, such platforms could be used to increase clarity and agreement between agencies concerning terminology, roles and responsibilities, as well as contributing to

more rural-appropriate and coordinated DRM in New Zealand (UNDRR, 2015). This lack of coordinating platform through which interfacing and communication could occur may have resulted in the divergent response priorities and parallel efforts observed in the Kaikōura earthquake case study, which found that government-led response structures and rural organisations often responded to the disaster in their own ways and within their own siloes.

The Project AF8 case study showed how valuable advancing coordination between researchers and practitioners can be, by bringing together many of the actors with key roles in rural disaster preparation, response, and recovery (such as critical infrastructure companies, regional councils, and large agri-businesses) (Chapter 4). However, membership in the initiative was voluntary, and Project AF8 did not have the legislative powers necessary to enforce this coordination, as recommended by Basher (2016) for a large coordination platform.

District and regional coordination platforms would provide opportunities to use the type of collaborative, scenario based planning carried out by Project AF8, while also have the potential to include the wider range of small rural organisations active in rural areas. Despite efforts to coordinate the response activities of rural organisations following the Kaikōura earthquake, most of these grassroots response arrangements acted parallel to, rather than integrated in, the official government response (Chapters 2 and 3). Thesis results suggest that the primary industry clusters that emerged to this end (such as TeamAg, or the Canterbury Primary Industries Adverse Events Cluster Group represented and led by a Rural Advisory Group) were mainly agribusiness focused, rather than on response support for the entirety of rural regions, which includes vulnerable populations such as the elderly, disabled, poor, or transient migrant farm workers.

Additionally, current New Zealand DRM legislation does not adequately account for rural needs and priorities, and so risks giving rise to DRM practices that are by default better aligned with urban needs. For example, emergency response efforts to engage with isolated communities following the Kaikōura earthquake were complicated by the CDEM priority (and mandate) to help the maximum number of people in the shortest amount of time, potentially disadvantaging sparsely populated rural regions. The CDEM focus on providing immediate access to basic human welfare needs (such as food, potable water, and temporary shelter) was found to not align well with the priorities of most farms and agribusinesses in the case study. Prioritising the distribution of basic welfare needs is appropriate in an urban earthquake setting, but often is less suitable in rural contexts, not just because the population density and numbers

are lower, but because rural populations are typically more prepared for isolation, and may not require food, water and shelter. The disconnect in response priorities is due in part to a complex legislative environment, as the same CDEM Act 2002 legislation applies to earthquake response in both rural and urban contexts, despite the very different settings (New Zealand Legislation, 2020).

Legislation was also found to constrain DRM in rural areas due to the administrative red-tape involved, and the inflexibility of some operational guidelines (Chapter 3). Thesis findings suggest that, again, this can be attributed to the lack of effective coordination mechanisms. Although national legislation calls for high levels of coordination and integration between agencies and across sectors, it does not provide the clear pathways required to accomplish it (New Zealand Legislation, 2020). In the Kaikōura earthquake case study, this legislative DRM environment was found to exacerbate tensions between local and national response arrangements due to a lack of clarity concerning organisational risk management roles and responsibilities in the rural setting.

Findings from this thesis also support the argument that economic capital, at both the local and national levels, plays an important role in enabling DRM decision-making. This is to be expected, as high-income nations have already been shown to have advantages in the resources and capacities available to address disaster risk reduction, response, and recovery options that may not typically be possible in low-income nations (Paton et al., 2000; Sperling et al., 2004; Mileti and Gailus, 2005; Baker and Refsgaard, 2007; Gaillard, 2010). While the broader field of economics was considered out-of-scope and not robustly explored as part of this thesis, both the Kaikōura earthquake and Project AF8 case studies point to the importance of a robust economy in preparing for, responding to, and recovering from rural earthquakes in New Zealand. The impacts of the Kaikōura earthquake would likely have been much greater and more severe had the central government not been in good financial standing and able to absorb the financial costs to the national economy (Sampson et al., 2017; Brown et al., 2018). Additionally, it is conceivable that if the organisations involved in Project AF8 (all of whom participated on a voluntary basis) had not had a measure of financial stability, they may not have been able to engage in, nor bear the financial and time-related expenses of, earthquake preparedness activities.

5.4. Opportunities to enhance the effectiveness of rural DRM in New Zealand

Thesis results point to: a need for more collaborative approaches to rural DRM using an engagement process similar to that used during Project AF8; better coordination and aligned priorities between rural residents, organisations, and responding government agencies through a mechanism that ensures accountability; and greater community involvement and ownership of disaster risk management, response, and recovery. Each of these themes are discussed in turn.

There is a growing global awareness of the need for collaborative approaches to inform DRM and support large cross-sector and interdisciplinary initiatives that address complex global issues such as disasters (Thomalla et al., 2006; Howes et al., 2015; Wyborn et al., 2017). This thesis stresses the importance and the value of co-creation methodologies in the rural DRM space. A key finding is that although the Project AF8 and Kaikōura earthquake case studies investigated rural DRM from broadly different angles, analysis of each independently indicated that more co-created approaches to rural DRM are required in New Zealand. Project AF8 was a compelling example of how a large, interdisciplinary research initiative can succeed, despite some challenges along the way. The co-creation methods used to address DRM decision-making during this initiative were perceived by interview participants to directly enhance evidence-based response planning of regional and local government, agencies, and infrastructure companies across New Zealand's South Island (Chapter 4). In part, this was enabled by the forum provided by Project AF8 for sustained dialogue between scientists and practitioners (including policy-makers), generating mutual understanding of professional needs and limitations on all sides of the science-practice-policy boundary. Participating practitioners were able to obtain a better understanding of the lengthy research time frames, funding cycles, peer-review processes, and publication needs of scientists. Conversely, scientists were exposed to the professional requirements of practitioners, their need to work within an environment characterised by uncertainty, and within a relatively rapid time frame. Thesis findings indicate this forum enhanced the effectiveness of rural DRM in the Project AF8 case study, suggesting similar strategies employed elsewhere would also be useful in enhancing the effectiveness of rural DRM for other contexts and circumstances.

Furthermore, analysis of the Project AF8 case study finds that evidence-based DRM decision-making and pre-event planning relied on the collaborative development of robust and

relevant shared knowledge of disaster risk. The interface between scientists and practitioners was found to be particularly important in this knowledge production. Chapter 4 examines the ways in which such knowledge was generated, shared, and used within a co-creation collaboration involving practitioners and scientists from a range of disciplines. Results reveal two important considerations regarding disaster risk information. First, content matters – effective co-creation is heavily context-specific. The knowledge that was particularly useful, for the practitioners and policy makers that helped to generate it, concerned the ways in which an event might impact vulnerable populations, or affect the functionality of exposed infrastructure and the built environment. Knowledge that was applicable in these areas helped facilitate practitioner and policy maker pre-event planning by increasing their understanding of the operational implications and logistical environments in which the disaster response was likely to take place. Working together with scientists made it possible to co-create knowledge that focused on interdependencies between systems and multi-hazard perspectives, and that was sensitive to dynamic changes in the disaster response system following mitigation decisions. Interviewed practitioners found this co-created knowledge vastly more valuable than information that simply characterised the natural hazard.

Second, as this would suggest, the processes used to generate and share knowledge of disaster risk were found to be essential in ensuring that this knowledge was scientifically credible and fit-for-purpose for use by practitioners. The co-creation processes developed within Project AF8 (to optimise interactions between members) and the engagement approach used for Project AF8 outreach to manage interactions between Project AF8 and the public were perceived by interviewed participants to be key to the success of the initiative.

While the Kaikōura earthquake and Project AF8 case studies were fundamentally different, operational experiences during the Kaikōura earthquake response and recovery contributed substantially to the knowledge development within Project AF8 by providing insights into some of the challenges likely to be faced by emergency managers after an Alpine Fault rupture. Thesis research into the Kaikōura earthquake case study focused on rural response and recovery to an earthquake from the grassroots and local perspectives, while the Project AF8 case study focused on pre-earthquake planning from the top-down perspective of government agencies and large organisations. Despite the disparate, yet complementary, insights into rural DRM approaches they offer, these case studies were intricately linked. The Kaikōura earthquake occurred during the first year (of four) of Project AF8, with many of the

same emergency managers and organisations involved in both response and recovery to the Kaikōura earthquake as well as the Project AF8 planning process. Experiences from the Kaikōura earthquake response and recovery fed back into the planning of Project AF8, creating a positive feedback loop which benefitted DRM decision-making. Analysis of the response to the Kaikōura earthquake (Chapters 2 and 3) indicates that the greater inclusion of rural perspectives, knowledge, and networks, as emphasised in Project AF8 (Chapter 4), would likely have increased the effectiveness of response and recovery decision-making after this North Canterbury event. Thesis results show that challenges to the Kaikōura earthquake response included coordination issues and misaligned response priorities between the responding government agencies, rural organisations, and rural residents. This tension might have been resolved by adopting a more inclusive and collaborative approach to rural DRM decision-making.

Some senior level emergency managers within Project AF8 attribute the success of, and public appetite for, the Project AF8 initiative (and associated rural DRM decision-making) to the revitalised public and political concern for earthquakes brought about by the Kaikōura disaster (Chapter 4). It is possible that Project AF8 efforts to focus on outreach, including raising public awareness and organisational interest in preparing for an earthquake event, were also factors in enabling and enhancing the effects of this rural DRM initiative.

Additionally, there is increasing recognition across a range of sectors on the need for expediency in responding to rural disasters, including the need to support farmers and the primary sector effectively (Flint and Brennan, 2006; Davis et al., 2010; OECD, 2012; Dailey and Starbird, 2016; Chapagain and Raizada, 2017; Van Niekerk et al., 2018; Haskins et al., 2019). In part, this is driven in New Zealand by a strong primary industries lobby that aligns with rural DRM needs to support the primary sector (Bullock, 2012; Strong and Tyler, 2017). Yet this recognition is yet to be matched by formally structured and broad-based cross-sector DRM coordination platforms (Basher, 2016). Although guiding national DRM legislation (the CDEM Act 2002) calls for a coordinated response, the implementation of this coordination remains open to the interpretation of individual agencies (New Zealand Legislation, 2020). Basher (2016) suggests that a mechanism that requires responding agency input, and holds them accountable to this, could enhance the effectiveness of rural DRM in New Zealand, but that such a platform would also need to allow for the voluntary participation of actors from outside of government. This would be particularly useful in rural areas where a number of rural

organisations are actively involved in DRM, but do not fall within the coordination guidelines provided by the CDEM Act 2002 (New Zealand Legislation, 2020). Findings from Chapter 3 show that while New Zealand's official response agency (CDEM) does encourage local response arrangements and continually seeks ways to help support these, the country continues to lack the larger, pan-agency, cross-sector, and widely recognised formal structures required to incorporate localized actors and logistical needs into the larger picture (as suggested for enhancing DRM effectiveness by Basher, 2016).

Incorporating a wider range of localised actors and logistical needs in this way could contribute more effectively to rural DRM decision-making informed by rural perspectives, and therefore be more likely to align with rural response priorities (Chapter 3). Without an effective mechanism for this incorporation, it was found to be more difficult for national level, and typically urban-based, responding agencies to grasp and address the extent of local rural impacts to disasters. It is especially important to include rural perspectives in rural DRM because of the inherent tendency for many urban-based emergency managers to automatically apply the same response strategies to the rural context that are used by default in more densely populated contexts (Chapter 3). For example, following the Kaikōura earthquake, thesis findings (Chapter 2) showed that rural communities experienced longer periods of isolation compared with local townships, reflecting the distinct response needs for these areas, and an opportunity for enhancing rural DRM effectiveness.

Greater community involvement in DRM is called for in the National CDEM Strategy vision statement, where a resilient New Zealand would have "communities understanding and managing their hazards" (MCDEM, 2007b). This document set the official government strategy for emergency management from 2007 to 2017, which coincided with the first years of this thesis research and write-up. Thesis findings align with this National CDEM Strategy by showing that the use of impact assessments by responding agencies would facilitate better and quicker understanding of the issues likely experienced in rural regions following a disaster (see Chapters 2 and 3). The inclusion of rural communities and organisations in the DRM planning process was found to encourage local ownership of risk management, response, and recovery, allowing communities to understand and manage their hazards (see Chapter 4) as was aspired to in the vision statement of the time. More recently, however, a National Disaster Resilience Strategy (MCDEM, 2019) has been developed and published, which sets the priorities for building New Zealand's resilience to disasters for the years of 2019 to 2029. This thesis, nearly

complete by the publication of the National Disaster Resilience Strategy, can nevertheless inform the implementation of the new strategy in the rural domain through the key themes it presents: managing risks, ensuring an effective disaster response and recovery, and enabling and supporting community resilience. Similarly, a National Climate Change Risk Assessment report (https://www.mfe.govt.nz/climate-change/assessing-climate-change-risk) is expected in late 2020, and this thesis, completed before the publication of this report, can show priority areas for implementation it in the rural space.

It was fortunate that this earthquake did not overwhelm the larger urban centres of Wellington and Christchurch, allowing their key infrastructure to remain operational. Christchurch was a gateway for response and recovery operations coming from the south to the regions isolated by the earthquake, and the upper South Island ports (Picton and Nelson) were gateways for resources coming from the north. Though both Christchurch and Wellington were subjected to shaking and some minor damage (Brundson et al., 2017; Cubrinovski et al., 2017; Henry et al., 2017), they were still able to contribute resources, personnel, and response efforts to the smaller rural communities which were heavily impacted by the event. As this may not be the case in future events, DRM planning specific to the rural context should help communities accept, and prepare for, the possibility that they may be isolated and without external aid for days or weeks before help arrives.

5.5. Limitations of approach

This thesis draws from, and contributes to, both social and physical scientific literatures. Therefore, the scope of contribution from each of these wider fields was necessarily constrained in order to balance input from both sides.

Additionally, the occurrence of the 2016 Kaikōura earthquake was both a limitation and an opportunity for this study. Prior to this event the Kaikōura and Hurunui districts had been chosen as a case study as part of a doctoral project focused on the development of decision support tools to enable rural-specific DRM by emergency managers, policy makers, and other disaster risk reduction decision-makers, including a range of members of rural communities and those involved in rural businesses. The Hurunui and Kaikōura regions were however among the most heavily impacted by the earthquake (NEMA, 2020b). In response to the emerging research needs and opportunities post-earthquake, disruption to the thesis was minimised by re-

orienting the thesis focus from decision support tools to rural disaster impacts, drivers of risk, and the response and recovery to the event.

While the 2016 Kaikōura earthquake provided a rich context for empirically investigating rural DRM, it also presented challenges associated with data collection, ethics, and overall research direction. Under other circumstances this research would have set out to gather qualitative data from a diverse range of interview participants from across the rural sector. However, given the enduring impacts of the earthquake at the time of interviews (approximately one to two years post-event) it would have been unethical and insensitive to increase the stress of rural populations by subjecting them to additional research pressures. This has been identified as a breach of fundamental ethical principles, most recently following the 2010 – 2011 Canterbury Earthquake Sequence (Beaven et al., 2016). Largely for this reason, perspectives from a wider range of rural society (including groups such as the elderly, disabled, and migrant farm workers) were not well represented in this study. Most interview and focus group participants were professionally trained emergency managers active in the response to the Kaikōura earthquake, or had an official response role in local and regional government. Efforts were made, however, to interview individuals that were well enough networked in rural communities to provide a degree of insight into the experiences of vulnerable communities.

Finally, it is important to note that while the thesis has focused on rural areas, the Kaikōura earthquake also caused shaking and resulted in structural damage in Wellington, New Zealand's capital (Brundson et al., 2017; Cubrinovski et al., 2017; Henry et al., 2017). While urban perspectives fell outside the immediate scope of the thesis, national-level participants contributed insights regarding rural DRM in general, and specifically related to this earthquake. Personally experiencing the shaking from this event, even in the capital, may have influenced their responses and perspectives.

5.6. Future research opportunities

Some important and exciting avenues for further research have already been described throughout the thesis. For example, the limitations in existing approaches to DRM point to the need for studies that further explore alternative methods for decision-making in DRM. This thesis has also highlighted further gaps in our knowledge and the need for additional studies exploring local contexts that can inform disaster risk governance. This section will outline other

possible directions for future research. The key areas, discussed in turn, are: a need to better understand rural contexts in high-income nations; the use of co-creation to manage DRM decision-making, a deeper understanding of the intangible and indirect losses and impacts of rural disasters, the integration of DRM with climate change adaptation (CCA) and development studies, and the generation of a legitimate evidence-base that can most effectively support DRM policy makers.

The field of DRM would benefit from a deeper understanding of disaster risk in rural areas of high-income nations. This would be best informed by a strong research base on the rural-specific impacts caused by disasters. Further case studies and empirical evidence would strengthen the scientific knowledge base around the fundamental drivers of rural disaster risk and the influence of context. This includes strengthening considerations for DRM with respect to the distinct rural 'culture,' as is studied in the field of rural sociology. For example, Loveridge (2016) highlights the uncertain and changing relationship between rural areas and government policy and funding in New Zealand, but the connection between this dynamic and DRM is under researched. Additionally, the process of 'land tenure review,' which has resulted in changes to rural land ownership and land use agreements between central government and the farmers who had multi-decadal leases on government-owned pastoral lands provides another layer of nuance (and in some cases tension) that might inform understanding of the interface between rural residents and government-led DRM efforts (Brower 2016; Brower et al., 2020). In New Zealand, as in other high income countries, evolving social, cultural, economic, technological, and natural environments in rural communities across the country continue to create new vulnerabilities which must be understood and appropriately considered in future rural DRM.

More studies are needed to better contextualise the approaches and processes used in the field of DRM with regards to the use of evidenced-based decision-making. Project AF8 showed that effective DRM benefits strongly from an engagement process at the science-practice-policy interface that can inform decision-making, and requires input from many different types of knowledge. Other DRM initiatives in New Zealand similarly use an engagement process at the science-practice-policy interface, however their processes do not appear to be as transparent and well documented as those used in Project AF8. Future research needs to better record and investigate the effectiveness of DRM engagement processes, and additional empirical evidence from other initiatives (and ideally a side-by-side comparison

study between them) would enable more effective knowledge transfer mechanisms and help guide efficient methods for future use.

Research is also needed to better comprehend the indirect losses (and gains) to rural areas following a disaster. For example, it is relatively easy to put a value on the physical and direct cost of repairing a road. It is less easy to determine the economic consequences and medium to long-term implications of this damaged road to the businesses and industries that rely on it, who may lose money because customers and suppliers can no longer reach them, or who may not be able to transport their goods to market. Indirect losses from disasters are more difficult to identify and measure than direct losses from disasters, but nonetheless empirical evidence and research towards identifying potential indirect impacts of disasters should be furthered. In addition to indirect economic losses, the intangible psychosocial effects of the Kaikōura earthquake on impacted communities requires further consideration, in particular with respect to the role and implementation (or not) of the existing national Framework for Psychosocial Support in Emergencies (Ministry of Health, 2016).

Aspects of DRM, such as building resilience, align with multiple other topic areas in the rural context, such as CCA and sustainable development. These topic areas are tightly linked, but would benefit from being holistically integrated with each other. For example, there are opportunities for DRM to incorporate aspects of development planning to facilitate reconstruction after an event, and for general use in guiding rural land-usage. Research that focuses on possible recovery paths to move forward after a disaster need to be in place before it happens. Also, the effects of global climate change are increasing hydro-meteorological disasters (and their impacts) in high-income and low-income countries alike. However there is a lack of scientific knowledge on how to best integrate DRM with the fields of CCA and development (Pelling et al., 2004; Thomalla et al., 2006; Schipper, 2007; Davies et al., 2009; Birkmann and von Teichman, 2010; Gaillard, 2010). Efforts towards enabling this integration have the potential to considerably reduce disaster risk and even possibly prevent future disasters, and could prove highly valuable to society.

Arguably most importantly, future research must continue to create an accessible and understandable evidence base that can support positive changes in legislation regarding DRM. To enable this, policy makers should be key stakeholders involved in the generation and sharing of disaster risk knowledge. In this way, applied DRM research can directly contribute to saving lives.

5.7. References

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